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Design of Concept for Future Coastal Research Vessel

(A flexible platform for TZS Research and Education)

Thesis submitted in partial fulfilment of the requirement for the degree of Master of Science in Technology.

Espoo, 11th December 2017

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Abstract of master's thesis

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Master programme Mechanical Engineering **Code** IA3027

Thesis supervisor Professor Kalevi Ekman

Thesis advisor(s) Professor Pentti Kujala

Date 11.12.2017 **Number of pages** 69+19 **Language** English

Abstract

This study aimed to develop a concept of research vessel that is suitable for the research and educational works of the Tvarminne Zoological Station as a marine research center, also to create a template that will aid other marine research stations with similar operations to TZS in selection of research vessels.

The study examined the technical characteristic and performance of some research vessels in operation in different regional waters of the globe including vessels in the United States of America, the United Kingdom and Finland, and the results were compared to other available test data and together analyzed.

The analysis of results provided a range of data that will assist in making selection of suitable and cost-effective concept design of research vessels, with appropriate combination of hull forms. Materials and Machineries.

Keywords Research Vessel, Concept design, Catamaran, marine research, Tvarminne Zoological Station, Archipelago

Preface

This thesis is based on the study carried out for the Tvarminne Zoological Station (TZS) of the University of Helsinki. The project was funded by Walter ja Andrée de Nottbeckin säätiö (Walter and Andrée de Nottbeck's Foundation) through the Aalto-yliopiston tekniikan tukisäätiö (Aalto University Technical Support Foundation).

My unreserved appreciation goes to my instructor, Professor Pentti Kujala for his generous advice and professional comments, and the entire TZS team of research experts including Alf Norkko, Joanna Norkko and Göran Lundberg for their support and educating comments. Also, my sincere gratitude goes to my supervisor, Professor Kalevi Ekman (Eetu) for his patience and support during the entire process of the study and thesis compilation.

This study provided me a lot of travel opportunities including visiting the University of Southampton’s Ocean and Earth Center, National Oceanography Center where I was able to see and explore the Research Vessel (RV Callista). A lot of thanks to Gary Fisher for the highly informative time we had together onboard the RV Callista. Also, many thanks to Janne Esa for his assistance in getting me some of the relevant materials and for the numerous times we travelled to and fro Hanko (TZS) by his car, the trips were fun and a lot educating.

Finally, I am most grateful to my family and friends, especially to my wife, for the love and support shown me through the times of this study. Above all, most grateful to God almighty for seeing me through.

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Nomenclature

Symbols	*Description/Definition*
L:	Length
B:	Beam
T:	Draft
L_e:	Length of entrance
L_m:	Length of Parallel Midship
α:	Waterline angle
φ:	Stem angle
ψ:	Flare angle normal to hull surface
ρ:	Density of water (Baltic Sea water 1005kg/m3)
∇:	Displacement of the hull
m:	Mass of displacement
S:	Wetted surface of the hull
L_{wl}:	Length of waterline
V_{OW}:	Open water speed
C_P:	Prismatic coefficient
C_F:	Frictional Resistance Coefficient
L_{Cb}:	Longitudinal centre of buoyancy forward of $L_{wl}/2$
F_n:	Froude number
R_e:	Reynolds number
C_w:	Waterplane area coefficient
P:	Power (Design Power)
R_T:	Total Resistance

R_F:	Frictional Resistance
R_{APP}:	Resistance of Appendage
R_W:	Wave-making and Wave-breaking Resistance
R_B:	Bulbous bow pressure Resistnace
R_{TR}:	Immersed Transom stern Resistance
R_A:	Model-Ship Correlation Resistance
R_T:	Total Resistance
R_{OW}:	Open Water Resistance
R_i:	Ice Resistance
R_c:	Crushing Resistance
R_b:	Bending Resistance
R_s:	Submersion Resistance
S_{APP}:	Wetted Area Appendages

Abbreviation

CCOM:	Center for Coastal and Ocean Mapping
CCU:	Coastal Carolina University
CPP:	Controllable Pitched Propeller
CTD:	Conductivity, Temperature and Depth
EPA:	Environmental Protection Agency
EVC:	Electronic Vessel Control
FINMARI:	Finnish Marine Research Infrastructure
FSICR:	Finnish Swedish Ice Class Rules
FPP:	Fixed Pitch Propeller
GA:	General Arrangement
GTK:	Geologian tutkimuskeskus (Geological Survey of Finland)
HELCOM:	Helsinki Commission
IMO:	International Maritime Organisation
IWW:	Industrial Workers of the World
JHC:	Joint Hydrographic Center
LOA:	Length Over-All
NOAA:	National Oceanic and Atmospheric Administration
NOCS:	National Oceanography Centre of Southampton
PC:	Power Control/Power Consumed
RPM:	Revolution per Minute
RV:	Research Vessel
TZS:	Tvarminne Zoological Station

1.0 INTRODUCTION

For many years, the Baltic Sea has been an attractive centre for research and education owing to its rich natural endowment. The Baltic which is one of the largest brackish body of water on earth, is a highly sensitive and interdependent marine ecosystem, giving rise to unique flora and fauna. It is surrounded by nine countries with over 85 million people most of which rely on its healthy and rich treasure for food, income and leisure activities. [1].

The rapid increase in human activities in the Baltic Sea coupled with the climate change in the recent decades has so far created more needs for research activities in other to sustain the region for the future generation to also benefit from its wealth and treasure. The Baltic Sea has in recent times, been one of the world's most intensely studied region with a large number of marine research centres [2]. Helsinki Commission (HELCOM) - the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" – having all of the nine Baltic coastal countries as well as the European Community as its contracting parties, has also in place an ambitious programme to restore the 'Good Ecological Status' of the Baltic marine environment by 2021 [3]. With the increase in research activities in the Baltic Sea and along its coast, comes the need for up-to-date research facilities development or upgrade as the need may be in order to meet up with the trend and pace of time which is an enormous challenge. All these basically and many other needs for effective and efficient research activity in and around the Baltic region has informed the need for this study.

1.1 Operational Study

Understanding the design requirement for a suitable Research Vessel that will operate within the coast of Finland from the Tvarminne Zoological Station requires understudying the station's operations and its research infrastructures especially the activities of the R/V Saduria, its purpose, scope of operations and capacity as it is a vital step to a better solution.

1.1.1 The Gulf of Finland

The Gulf of Finland is the easternmost part of the Baltic Sea, bounded by Finland, Estonia and Russia, having shallow depth averaging about 40m but with uneven topography at the floor. The waters of the Gulf of Finland are among the freshest in the Baltic Sea and has a decreasing salinity of the brackish water from 6% in the western side to 2% in the eastern part, with the largest fluctuation of the water level occurring in the eastern side. Because of the low salinity level of the Gulf of Finland, the eastern part is usually covered with ice during the winter months, thereby causing disturbance to the shipping routes. [4]

The TZS is located at the eastern entrance to the Gulf of Finland, as such it is characterised by a longer season of frozen waters with thin layer of ice span across the surface of the water at the entrance to the Gulf, making navigation almost impossible for non-ice going vessels. Because of the longer period of this icy condition, research activity from TZS at most part of the year is quiet difficult and challenging.

Figure 1: Location of the Tvarminne Zoological Station at the entrance to the Gulf of Finland (Google)

1.1.2 Finnish Marine Research Infrastructure -FINMARI

Currently, Finland boast of a couple of marine research infrastructures as put together by FINMARI (a framework of research infrastructure and facilities in Finland). FINMARI as a joint research framework for the Baltic Sea is having a joint infrastructure development plan that is based on addressing the multiscale variability of the marine environment through the synergetic integration of the research foci of partnership. This partnership has in collaboration three Finnish research institutes three Universities, and a state-owned shipping company [5]. In this synergy is basically five major research vessels that operate within the northern coast of the Baltic (the Gulf of Finland), with each vessel having its characteristic domain of operation and capacity in terms of number of personnel onboard per time, and instrumentation depending on the required operations, with their specific strengths and limitations. These vessels include the R/V Aranda, Aurelia, Geomari, Muikku and Saduria [6].

Of the five vessels operating under the FINMARI infrastructure, R/V Aranda, owned by the Finnish Environment Institute (also known as SYKE) is the largest vessel in the fleet. Built with modern state-of-the-art facility for the purpose of scientific research in the Baltic Sea but has the capability of operating in all Seas. This vessel (R/V Aranda) have had its facilities stretched in recent times due to the vast nature of research needs within the region. This is largely due to the fact that the other vessels in the fleet, including R/V Geomari, Aurelia, Muikku, and Saduria are relatively smaller and have their operations strictly limited, especially to the Gulf of Finland and the Finnish Archipelagos. The R/V Saduria, been the smallest Vessel in the fleet of FINMARI, has been selected to be the case study and centre of investigation for the purpose of this study. Therefore, designing a concept for a suitable cost effective state-of-the-art vessel that will complement the activities of the R/V Saduria and the entire research infrastructure of FINMARI within and around the Finnish coast especially the activities of the Tvarminne Zoological Station (TZS) is the basis of this study.

1.1.3 Tvarminne Zoological Station (TZS)

TZS belongs to the faculty of Biological Science of the University of Helsinki, and it is a marine station located at the entrance to the Gulf of Finland in the Baltic Sea. It serves as a centre for a large variety of high quality Biological and ecological research, and also offers facilities for field courses, symposia, and seminar [7]. Established in 1902, though with a history that dates back to 1880s, TZS has over time metamorphose from just a zoological summer laboratory to what it is today –a station that prides itself in outstanding research and education activities, with thousands of projects and publications to its credit. The station plays host to dozens of scientist and researchers annually, and the number has been increasing rapidly in recent times, thereby putting pressure on the limited facilities. With the current vessels own by the station consisting of two large boats including R/V Saduria (14.4 m) and R/V J.A Palmen (10.3 m) alongside several other smaller boats for coastal sampling [6], the station needs to upgrade to live up to its expectation in securing the research activities along the Finnish archipelagos and the Baltic region for the near future.

Figure 2: Tvarminnen Zoological Station. [5]

1.1.4 R/V Saduria

R/V Saduria is currently the largest vessel of the Tvarminne Zoological station but stands as the smallest in the fleet of the Finnish Marine Research Infrastructure (FINMARI). With a lot of limitations, the R/V Saduria has been working under high pressure in the recent times as it is been used for operations way out of its original design. Aside from the fact that Saduria is too small in size, it is faced with other limitations as:

i. The cost of maintenance is getting high, thereby making it difficult to manage as it is no longer cost effective. This is certainly due to the stress induced by the level of usage coupled with the fact that it wasn't designed for its current operations as such increasing the rate of wear.
ii. The mall size also is a major setback especially for the purpose of education as study group most often have to be subdivided into smaller groups to make different turns or shift, thereby affecting the understanding level of the student as conditions are never the same at different times to carry out the same study.
iii. R/V Saduria Cannot operate in the slightest ice conditions, whereas the operational location of TZS often experience longer period of frozen water, making it extremely difficult and most often impossible for researchers to go out for sampling or for other field exercises. This actually has posed one of the greatest challenges and currently of most concern to the station. Solving this problem will be a breath of fresh air as the station will then be able to carry a year-round operation without any hindrance.

Figure 3: R/V Saduria. [6]

1.2 Problem Statement

This study focuses on the need for modern state-of-the-art research facilities in order to enhance activities of researchers within the Gulf of Finland; along the coast and archipelagos, and to boost the infrastructural capacity of the Finnish Marine Research Infrastructure (FINMARI). The problem is to design a modern state-of-the-art concept of research vessel that can replace the current R/V Saduria, with capacity to suit both the current and future research activities and requirements of the Tvarminne Zoological station.

1.2.1 Research Aim

In line with the changing trend of the research activities along the coast of Finland and archipelagos, this study is primarily aimed at;

i. Developing a concept design for a suitable and cost effective state-of-the-art research vessel that will incorporate modern scientific research equipment and machinery on a flexible working platform for both research and educational purpose for the Tvarminne Zoological Station (TZS).

ii. Designing a concept that shall serve both as a template for future design and for the selection of Research Vessels (parameters) for different workstations not only for the Gulf of Finland and Finnish coastal region but also for the entire Baltic Sea region and other Sea regions with similar working environment and operating conditions.

1.2.2 Research Objectives

The objectives of this study include (but shall not be limited to) the following:

i. Investigating the available vessels that share similar work locations and operation characteristics and possible design concept with both the current vessel (R/V Saduria) and the proposed concept as per the predefined requirements by the TZS. This will help in establishing certain basic criteria to be considered different in the future design.
ii. Investigating different hull design (basically the monohull and catamaran) for different working conditions and operations requirements.
iii. Investigating different operating conditions and working environment in relation to the reference station (TZS) in relation to the open water and icy conditions.
iv. Investigating different design material (basically Aluminium and Steel) and optimization for different vessel and operating conditions
v. Carry out cost analysis and evaluation of financial obligation on different design concept for different work locations and operating conditions. This is of great importance to this study, as it will hence establish an optimum design concept that will be suitable for different work station especially the reference station (TZS).
vi. Finally, concept selection and recommendation for optimum design.

1.3 Importance of Research

This study is of great importance as it shall not only address the immediate need of the Tvarminne Zoological Station but shall contribute to FINMARI's research infrastructural network, thereby enhancing and broadening the scope of research activities in the Baltic Sea. Also, as it is a design concept with the future trend in consideration, it shall equally serve as a template for future facilities upgrades or new facilities development for similar or closely related work locations and operating conditions as per the reference station (TZS). This shall not be limited to just the Gulf of Finland or the Baltic Sea, but to as many locations and Seas research as may be required.

1.4 Scope and Structure of Study

The scope of this study is to design a concept for research vessel suitable for operations that will fit in the Finnish Marine Infrastructure, and the focus mainly is on the basic requirement for a suitable research vessel that will meet up with the current trend of research activity within and around the coast of Finland, its archipelagos, and the Baltic Sea region at large. In order to achieve this, first of all an investigation will be done on the current state of research vessels within the region, alongside other vessels that share similar characteristics with respect to scope of operation, nature of operation, and some basic parameters including size, hull forms, machineries and equipment.

Secondly, the characteristic parameters of the investigated vessels will be synthesised alongside some pre-established criteria in order to establish the components of similarities and differences, which will form the basis for the selection of certain design parameters and operational profile for the prospected research vessel.

Finally, from the study and investigation result of selected Research vessel and environment, a suitable selection of components and basic parameters combination will be established to form the basis for a suitable research vessel that will satisfy the predefined needs and operational environment as stated in the problem statement. In addition, from the selected parameters, a cost analysis of the different component selected, and the cost/manufacturability selected component/materials will be done for a cost effective design solution.

2.0 CURRENT STATE OF RESEARCH VESSELS

There has been a rapid increase in marine research activity in the Baltic region which has into given rise to the need for more research vessels, and currently there are five active research vessels in operation within the Finnish coast according to the Finnish Marine Research Infrastructure [6]. The operations of R/V Saduria and the other Research vessels operating within and around the coast of Finland is better understood by the examination and study of other vessels that has operational profiles and characteristic parameters of interest similar to the reference vessels at different marine research institution in different regions and seas around the globe.

Figure 4: National Oceanography Centre Southampton [8].

2.1 Ocean and Earth Science, University of Southampton

The Ocean and Earth Science of University of Southampton in collaboration with the National Oceanography Centre of Southampton (NOCS) boast of a well established reputation for outstanding research in the field of Ocean and Earth Sciences because of the capacity of their research facility especially the capacity of operations and activities of the R/V Callista. The NOCS combines the Southampton-based part of the Natural Environment Research Council's National Oceanography Centre, and the University of Southampton's Ocean and Earth Science. The students of the Ocean and Earth Science of University of Southampton are based at the prestigious NOCS, with other groups of scientist and engineers making up one of the world's largest groups of scientists and engineers devoted to research, teaching and technology development in ocean and earth science. The Centre (NOCS) is well equipped with modern instrumentations, laboratory and other state-of-the-art facilities. Just like the Finnish Marine Research Infrastructure (FINMARI), the NOCS is the operational base for UK's fleet of deep sea research vessels and other equipment, NOCS also houses the UK's collection of ocean sediment cores, as well as the National Oceanographic Library. [8]

2.1.1 R/V Callista

The R/V Callista belongs to the Ocean and Earth Science department of the University of Southampton United Kingdom, it is used by staff and students for a range of field work and research activities. The R/V Callista is one of the three purpose-built vessels of the University, with designed capabilities to undertake various task including:

- Deploying of scientific equipment
- Collection of biological, chemical and sediment samples
- Surveying
- Diving operations
- Geophysics
- Educational visits by external groups including schools, colleges, universities and others. [9].

R/V Callista is a Hydrographic Surveying vessel, designed basically for the purpose of teaching and academic research works. Callista is a Catamaran vessel made of Aluminium body with a large rear deck and A-frame for equipment deployment. R/V Callista is equipped with the basic equipment required for its operation as contained in the technical data sheet (see the appendix B). R/V Callista was built by Tyovene Oy and delivered to the Ocean and Earth Science, National Oceanography Centre Southampton in 2005. Tyovene Oy is a Finnish company with about 30 years' experience in building a variety of work vessel ranging from Road ferries, Passenger Vessels, SAR Vessels, multipurpose vessels, Catamarans etc. [10]. Tyovene Oy got the decision to build the vessel (R/V Callista) on the basis of quality, price and specification which took into account extensive detail of everything a workboat of such category would require. And the vessel (RV Callista) has been living to expectations, the institution and all users are happy and satisfied with the operations of the vessel as testified by Gary Fisher [11]

2.1.2 R/V Callista; Technical Specification

The R/V Callista has a total length of 19.75m long, 7.40m beam and weighs 50 tonnes with a top speed of 14 knots. R/V Callista has a fuel capacity of 6000 litres with given range of 400 nautical miles. Callista can comfortably accommodate 36 passengers, but she typically sails with around 25-28 adults onboard [9]. R/V Callista is equipped with a twin 650hp Scania D12 marine diesel engines which drive the 890mm Radice S4 bronze propeller through a Twin Disc MGX 51124A gearbox with ratio of 2.04:1. Also, a small air-cooled Kubota Nanni 4.220 HE auxiliary genset which can power all onboard hydraulic systems when the vessel is aground. Callista boasts of a well equipeped state-of-the-art bridge with comprehensive instruments including Trimble DSM132 DGPS and a Nav PC with an 18in monitor running Transas Navi-Fisher 3000 with a radar interface board and navtex. A LAN has Trimble HydroPro survey software installed. The magnetic compass is a Suunto D135 whilst Simrad has supplied a CZ54D DGPS receiver/plotter/radar/ sounder, AP 50 autopilot with thruster interface, two RD 68 Class D DSC VHF transceivers, an AX 50 GMDSS handheld VHF, and an IS 15 wind system [12]. Detail on the technical specifications can be seen as in appendix B.

Figure 5: R/V Callista [9]

Table 1: R/V Callista Technical Specification [9]

Vessel Specifications	
Length overall:	19.75m
Beam:	7.40m
Freeboard:	1.70m
Draught:	1.80m
Max Speed:	14kts
Cruising Speed:	10-12kts
Range:	400nm
Accommodation:	4 berths
Certification	
UK Class IV Passenger Vessel - max 36 passengers	
Workboat category 2, 60mls from a safe haven - max 12 passengers	
Deck	
Hydraulic Platform Stbd side	
Knuckle Boom Crane	
3 Phase and Hydraulics available on working deck	
Stern 'A' frame & winch	
4.5m RIB with outboard motor	

2.2 Coastal Carolina University

Coastal Carolina University commonly referred to as CCU is a public, state-supported, liberal arts university in Conway, South Carolina, United States - located in the Myrtle Beach metropolitan area. Founded in 1954, CCU became an independent university in 1993. The university is a national sea-grant institution and owns part of Waties Island, a 1,105-acre (4.47 km2) barrier island which serves as a natural laboratory. The department of Coastal and Marine Systems Science is a department in the College of Science, and it boast of best science support available for effective management of the coastal environment. The Coastal and Marine Systems Science department also houses four vessels including the R/V Coastal Explorer, BERM Boat, Privateer and the Leading Lady. Both the BERM Boat and Leading Lay are smaller crafts that are only suitable for shallow waters, but the R/V Coastal Explorer is the latest and biggest in the fleet and currently the pride of the department. She boasts of capacity and capability to execute a wide range of research and educational task, and rightly equipped with promising potential to allow for the understanding of the complex coastal systems and natural resources which make ups a significant portion of state economy. [13]

2.2.1 R/V Coastal Explorer

The R/V Coastal Explorer belongs to the Coastal Carolina University (CCU) in the state of South Carolina, United States of America. According to professor Paul Gayes, director of CCU's school of Coastal and Marine system science at the event of the launch ceremony of the vessel; "acquisition of the Coastal Explorer will expand CCU's research initiatives across board. [13].

Figure 6: Coastal Explorer [14]

The vessel R/V Coastal Explorer was built in 2013 by Armstrong Marine Inc. for the Coastal Carolina University Center for the purpose of Marine and Wetland studies. R/V Coastal Explorer is a Survey Vessel, designed and built for Education, research activities in oceanography, and survey operations including taking underwater video and Ocean floor mapping, deploying of buoys and taking of research samples, and many more.

2.2.2 R/V Coastal Explorer: Technical Information

R/V Coastal Explorer is designed and built with a displacement Catamaran hull. Made from aluminium, the vessel has a passenger carrying capacity of 22 persons, with technical details as given in Table 2 below. R/V Coastal Explorer is design and equipped with modern state-of-the-art equipment with capacity to enable scientists accomplish crucial survey tasks efficiently and accurately. The design of the R/V Coastal Explorer is a breakthrough in for the

Coastal Carolina University and host community as she has the potential to open the door to a new world of marine research. [15]. See as contained in Appendix B.

Table 2: R/V Coastal Explorer technical Information [15]

Hull	LOA 54' (16.5m)
	Beam 18' (5.5m)
	High Speed Catamaran
Deck Accessories	Hand rails
	Antenna/radar mast
	Roof access ladder
	Port and stbd boarding doors
	(2) Engine room hatches c/w gas assist springs
	A-frame c/w Pullmaster PL2 winch
Superstructure	Fwd leaning wheel house
	Walk around cabin c/w raised wheelhouse and boat deck
	Five (5) Survey stations
	Captains Helm
	Marine grade non-skid flooring
	Head compartment c/w electric marine toilet & sink
	Shower c/w adjustable rail for shower head
	Counter c/w refrigerator
	Wallas Nordic DT diesel stove/heater kit
HVAC	(2) 18,000 BTU Dometic AC units with heating core for main cabin
	(1) 27,000 BTU Dometic AC units with heating core for wheelhouse
	Wallas 22 Dt Diesel Heater for wheelhouse
Electrical	12VDC system
	50 amp shore power inlet
	Northern Lights diesel generator 20kW
	Twin 6.7L 450HP FPT Diesels

Power & Propulsion	ZF280-1A marine gears
	(2) 4 blade propellers

2.3 R/V Gulf Surveyor

R/V Gulf Surveyor is a state-of-the-art research vessel designed for the Center for Coastal and Ocean Mapping Joint Hydrographic Center (CCOM/JHC). CCOM/JHC is a research institute whose activities focus on developing tools to advance ocean mapping and hydrography, and also to train the next generation of hydrographers and ocean mappers. JHC is a formal corporative partnership between the University of New Hampshire and the National Oceanic and Atmospheric Administration (NOAA). As such, the vessel is built with the intension both to educate and advance research activities in order to promote and foster the education of hydrographers and ocean-mapping scientist to be able to meet the rising needs of both government agencies and private sectors. Built by All American Marine (Bellingham, WA), R/V Gulf Surveyor is one of the two research vessels owned and operated by the CCOM/JHC, she is the newest. Built in 2015 and commissioned in January 2016, the R/V Gulf Surveyor is built with the latest available technology to provide a balanced combination of stability and comfort at different sea state in order to guarantee efficient and accurate scientific research activity. [16]

Figure 7: Gulf Surveyor. [16]

2.3.1 R/V Gulf Surveyor; Technical Data

The R/V Gulf Surveyor is a 48-ft (14.63m) twin-screw, propeller-driven Catamaran, with a certified capacity of 18 passengers on a coastwise route in the gulf of Maine. Built by All American Marine Inc., R/V Gulf Surveyor is equipped with a twin Cummins QSB 6.7L 184kW (247bhp) @2600rpm marine diesel Engine, and 2 x fixed 5-blade propellers. See detail on technical specifications as in the appendix C.

Performance

Gulf Surveyor has a top speed of ~18kts and cruises at ~14kts. Her minimum operating speed is ~3kts while towing scientific gear. Speed is limited to ~8kts during survey operations depending on the sonar mounted.

According to Professor Lee Alexander (Research Associate, Professor Emeritus CCOM), "the research vessel (Gulf Surveyor) built in Billingham Washington, like many vessels, looking at the requirement (at CCOM) and what is available, she is a uniquely designed catamaran, very stable and suitable for hydrographic survey. She is a multi-mission research vessel, capable of doing many different type of things, and one of the key feature is that the vessel is able to perform state-of-the-art ocean flow mapping". [16]

Table 3: R/V Gulf Surveyor; Technical Data

Categories	**Specifications**
Hull	Catamaran
	Length: 48-ft (14.63m)
	Beam: 17ft (5.2m)
	Draft: 4.6ft (1.4m)
Performance	Top speed ~18kts
	Cruise speed ~14kts
	Minimum operating speed ~3kts
	Capacity is 18 passengers
Deck Equipment	Retractable transducer strut that vertically articulates through a ~35" x ~69-15/16" moon pool door
	Morgan Marine Model 300.4 Hydraulic Crane
	DT Marine Model DT5005EHLWR electro-hydraulic winch

	A-Frame (SWL 2000 lbs)
	Universal Sonar Mount Foil Z-pole
	Davit (200 lb capacity) with open block and motor assisted windlass
	Capstan winch
	(2) Swim platforms with dive ladder and tank rack

2.4 R/V Geomari

R/V Geomari is one of the vessels among the fleet of the Finnish Marine Research Infrastructure (FINMARI). She is jointly owned by the Geological Survey of Finland also know in Finnish as Geologian tutkimuskeskus (GTK) and the Finnish Naval Research Institute. She is equipped with state-of-the-art science research equipment including a seismic signal equipment (250-1300 Hz), a Klein 3000 Sidescan Sonar (100/500 kHz), research echosounder (MD 28 kHz), Chirp Sonar (3 – 9 kHz), Multibeam Sonar and seabed sediment sampling equipment. R/V Geomari is designed for shallow water operations and equipped for multiple research task, with open stern (40 m^2) and a wet laboratory that can be configured to support a wide range of studies. With the aid of Differential Global Positioning System (DGPS) and dynamic positioning (DP) system, R/V Geomari is capable of holding still at a station thereby, enhancing accuracy of research data/sample collection. [17]

Figure 8: R/V Geomari. [18]

2.4.1 R/V Geomari; Technical Specification

R/V Geomari is an aluminium-body catamaran, built in 2003 by Mobimar Oy, for the purpose of sea floor mapping and other research activities along the coast of Finland and for the study of the Baltic Sea environmental conditions. She is designed with a capacity for 6 persons, and equipped with modern survey equipment for operations in the domestic region III traffic area, including the open sea and shallow waters. R/V Geomari has a Length overall (LOA) of 20m and measures 7.6m across (Beam). She is has a gross tonnage of about 75tons and is equipped with dual 700hp (522kW) Caterpillar diesel engines that powers a waterjet propulsion system. [19] The Table 4 below shows the technical specifications of R/V Geomari.

Table 4: R/V Geomari; Technical Specification

Categories	**Specifications**
Hull	Catamaran
	Length 20.0m
	Beam 7.6m
	Draught 0.9m
Performance	Cruise speed 20knt
	Operating Range 300 nautical miles
	Crew 3 persons
Survey Equipment	Atlas FS20 (20-200) multibeam echosounder
	Klein 3000 dual frequency side scan sonar (100kHz / 500kHz)
	Research sonar probe (28 kHz)
	Massa TR-61A Chirp (3,5-8 kHz)
	ELMA reflection seismic equipment (250-1300 Hz).

Table 5: Geomari Technical data [6]

Technical specifications:
Length 20.0 m
Beam 7.6 m
Draught 0.9 m
Gross tonnage 75 t
Power Dual 700 hp (522 kW) Caterpillar diesel engines, a waterjet propulsion system
Cruising speed 20 knots, normal operating speed ca. 4 knots
Operating range about 300 nautical miles
Crane with max load of 500 kg.
Berths for scientists 3
Crew 3 persons

3.0 DESIGN SYNTHESIS

The development of the flexible work platform for TZS considers the mission specification and general operational profile, then the vessel operational characteristics in terms of size/capacity, equipment, and regional classification. Also, the operational characteristics of the different reference vessels are synthesized thereby creating a template from which a suitable combination of characteristic profile is selected to suite the desired operational profile for the TZS and other similar work station as may be required.

3.1 Mission

The basic determinant of any research vessel design is the mission, why is the vessel needed, what kind of operation is it meant to perform? These are the kinds of questions that the mission statement seek to answer as such, laying foundation for the basic requirement for the vessel. As stated in chapter 1 of this study, this proposed vessel seeks to replace the existing Saduria, which mission is to carry out high level Biological and Zoological research along the coast of Finland and archipelago. Although this proposed vessel seeks to replace the Saduria, its mission is not limited to the current operation of the Saduria, rather it is a design for the future with possibilities of extended oceanographic research possibilities along the coast and Archipelagos of Finland and the Baltic this as the needs arise.

The primary mission and performance guide for this concept is for daily sample collection trip from TZS, carrying standard scientific equipment for sample collection, on-board laboratory (wet and dry work station). Examples of specific tasks the vessel should accomplish include:

- Deployment and recovery of sampling equipment such as plankton net, sediment corer and grabs etc.
- Capability for small-scale moorings
- Capacity to tow large size trawl nets.
- Convey students and scientist on research field trip
- Store samples at required temperature and conditions

Combining all these operational or mission profile into one vessel require that the vessel has sufficiently suitable deck space and work station (Laboratories), and excellent seakeeping ability for limited motions (stability) in every condition in order to scientific research efficiency and maximum productivity. Another important consideration is that this vessel be able to support wide range of equipment and research activities and that is why it is referred to as a flexible work platform.

3.2 Hull form and Material

Hull form design is one of the most important design criteria that is considered at the concept phase design, this is because almost every other criteria largely depends on the hull form. The selection of the hull form depends largely on the predefined mission and operational characteristics of the vessel.

The consideration of the suitability of different of hull forms for a vessel is done at the concept stage of the design such that the major operational economics is established. This is because as the design progresses through to the production stage, it is becomes difficult and expensive do effect many changes to the hull form as most of the other aspect of the design is depends on it.

As much as the hull form is of significant importance in the concept phase of design, the material consideration is equally of importance as the hull form also depends on the selected material. An efficient hull design comprise a good optimisation of material selection and hull form with respect to the operating environment.

3.2.1 Monohull Vs Multihull (Catamaran)

In the last three decades, the multihull vessel has been a centre of interest for sporting and oceanographic research. This is basically due to their transverse stability and large space area (beam wise). Also, the multihull vessels show good seakeeping characteristics as compared to the monohull vessels. The seakeeping characteristics and transverse stability are some among the important criteria considered in selecting type of vessels, as they influence key aspects such as passengers comfort, operations limit, speed and integrity of structures. [20]. From the initial establishment of the operational areas and conditions of the proposed vessel, stability and work space area are key consideration as such, the selection of the Catamaran for it suitability in meeting this predefined conditions. Also, carrying of sophisticated scientific equipment requires high level stability at all headings and sea states. Catamaran has been proven over in recent decades to possess such capability to maintain good level of stability comparative to monohull, nevertheless, certain analysis are carried out to uphold this assertions.

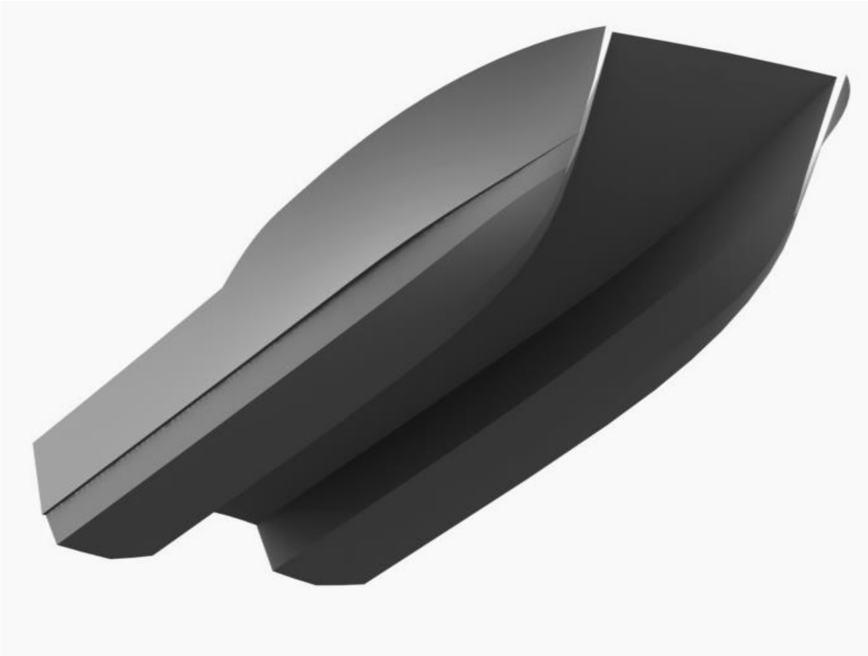

Figure 9: Hull form (Catamaran)

Below are tables of some research data from experiments conducted by Richard B Luhulima, D. Setyawan and I.K.A.P Utama, to show the level of stability and seakeeping characteristics of different vessels with different hull forms including Monohull, Catamaran and Trimaran, taking into account the all the motions and degrees of freedom at different sea state.

As can be seen in Table 6 below, for the two different experimental data as recorded by Richard B Luhulima, D. Setyawan and I.K.A.P Utama, (Maxsurf and AQWA), the Catamaran can be seen to be more stable than both the Monohull and Trimaran at the different heave angles for which they were test at sea state 5. These experimental data has shown that the catamaran is much more stable at heave motions. Also, the Table 7 below shows the stability level of the Catamaran over her counterparts (Monohull and Trimaran) at the different pitch angles experimented for Sea state 5. The Catamaran shows a more stable characteristics at the 90 degrees pitch angle both for the Maxsurf and AQWA experimental data.

Table 6: Heave motion at sea state 5 and Fn 0.3 [20]

Tool	Vessel type	Heave at various wave angle (m)				
		0	45	90	135	180
Maxsurf	Monohull	0.47	0.55	0.72	0.63	0.57
	Catamaran	0.14	0.12	0.18	0.19	0.19
	Trimaran	0.58	0.28	0.25	0.23	0.24
AQWA	Monohull	0.12	0.43	0.56	0.16	0.44
	Catamaran	0.21	0.03	0.26	0.06	0.11
	Trimaran	0.43	0.17	0.36	0.15	0.13

Table 7: Pitch motion at sea state 5 and Fn 0.3 [20]

Tool	Vessel Type	Pitch at various wave angle (degrees)				
		0	45	90	135	180
Maxsurf	Monohull	1.25	1.19	0.57	1.39	1.58
	Catamaran	1.78	0.86	0.55	0.75	0.86
	Trimaran	11.77	1.66	0.67	0.82	0.95
AQWA	Monohull	1.36	0.99	0.08	0.49	1.41
	Catamaran	0.94	0.56	0	0.63	0.49
	Trimaran	11.08	1.63	0.28	0.5	0.5

Table 8: Roll motion at sea state 5 and Fn 0.3 [20]

Tool	Vessel Type	Roll at various wave angle (degrees)				
		0	45	90	135	180
Maxsurf	Monohull	0	4.16	8.61	5.13	0
	Catamaran	0	2.06	4.07	3.33	0
	Trimaran	0	1.97	4.41	3.11	0
AQWA	Monohull	0	3.84	8.51	4.32	0
	Catamaran	0	0.8	1.14	0.8	0
	Trimaran	0	0.39	0.64	0.21	0

In similar manner as in Table 6 and Table 7, the data presented in Table 8 above shows the characteristic performance of the different hull forms of vessels experimented at Sea state 5 for different Roll angles. Comparing the data from the Maxsurf and AQWA for the Roll motion at different Roll angles, the Catamaran shows an irregular stability relative to the Trimaran. At angles below 45 degrees for AQWA data, the Catamaran is seen to be more stable than the Trimaran and Monohull. But at Roll angles higher than 45 degrees and below 180 degrees, the Trimaran shows a more stable characteristic behaviour than the Catamaran. On the other hand for the Maxsurf data, the Trimaran shows a more stable characteristics at all Roll angles experimented.

3.2.2 Aluminium Vs Steel hull

Generally, there are several advantages of aluminium over steel in structural design even in the marine industry. But the choice of material is dependent on some factors such as cost, operation and maintenance over the expected service life and also, fabrication cost. Some advantages of the aluminium over steel hulls in vessel design include:

- Low weight with appreciable strength; this is one of the major advantages of aluminium over steel. The weight of a vessel made from aluminium is about half the wright of same vessel built of equal strength from steel. Very important to note as relate to this design is that, a supper structure from aluminium lowers the centre of gravity of the vessel, thereby improving its transverse stability.
- Another important advantage of aluminium over steel in marine structure design is the increased corrosion resistance ability. An aluminium hull vessel has little or no need for corrosion protective paint as bare aluminium form aluminium oxide coating on its surface that prevent its material from corroding. This certainly is a huge cost savings as corrosion is one of the major problems in the marine industry.

Although on economic realities, the material cost of the steel is far less expensive than Aluminum, making it quite difficult to quickly draw the conclusion as on which material to settle for. But for the trade-off, a closer look at the major concern and vessel requirement will result in the final determining factor for the material selection.

The most commonly used marine Aluminum alloys are the 5000 and 6000-series, and in the recent decades, the interest for the use of these Aluminum alloys has increased, with evidence of international interest in aluminium ship structures in the International Forum on Aluminum

Ships, of which the fifth took place in Tokyo in 2005, and the Ship Structure Committee (SSC) has recently completed a number of Projects concerning aluminum ship structures including:

- SSC-410, Fatigue of Aluminum Structural Weldments
- SSC-439, Comparative Structural Requirements for High Speed Craft
- SSC-442, Labor-Saving Passive Fire Protection Systems for Aluminum and Composite Construction
- SR-1434, In-Service Performance of Aluminum Structural Details
- SR-1448, Aluminum Marine Structure Design and Fabrication Guide. [21]

Even though both the 5000 and 6000 series aluminum alloys are good materials for marine structures, the 5000 series Aluminum alloy has been considered and selected for this proposed concept because it has shown excellent corrosion resistance in service with some bare hull for decades. Also, the 5000 series aluminum alloys has undergone a lot of corrosion testing in sea water, a lot of these testing took place between 1950 and 1960. Sea water test was conducted for three different 5000 series aluminum alloys (including 5052, 5056, and 5083), and the report shows that the maximum pit depth in the three 5000 series alloys was 0.18mm and 0.86mm after five years and 10 years of immersion in sea water respectively. [21]

3.3 Propulsion System

The propulsion system selection is key to achieving the required operational capabilities. For a research vessel design to achieve a wide range of both scientific and academic success, a proper consideration of the propulsion system is critical, and that is the reason this design selection takes into account the operational need of the vessel. One very important requirement for this design is manoeuvrability and ability to achieve accurate positioning system as may be required for some special scientific operations. As such, the need of a propulsion system that guarantees effective and efficient positioning control. For proper selection, the pros and cons of the two basic types of propeller were examined; the Fixed Pitch Propeller (FPP) and the Controllable Pitch Propeller (CPP).

3.3.1 Fixed Pitch Propeller (FPP) Vs Controllable Pitch Propeller (CPP)

The controllable pitch propellers (CPP) are particularly suitable for workboat that require variable propulsion power conditions in terms of speed, bollard pull, manoeuvrability (as in fishing boats, tug boats, supply vessels and other utility vessels). The technical and economic advantages as relates to required operational capability are quite numerous, some of which are stated below. [22]

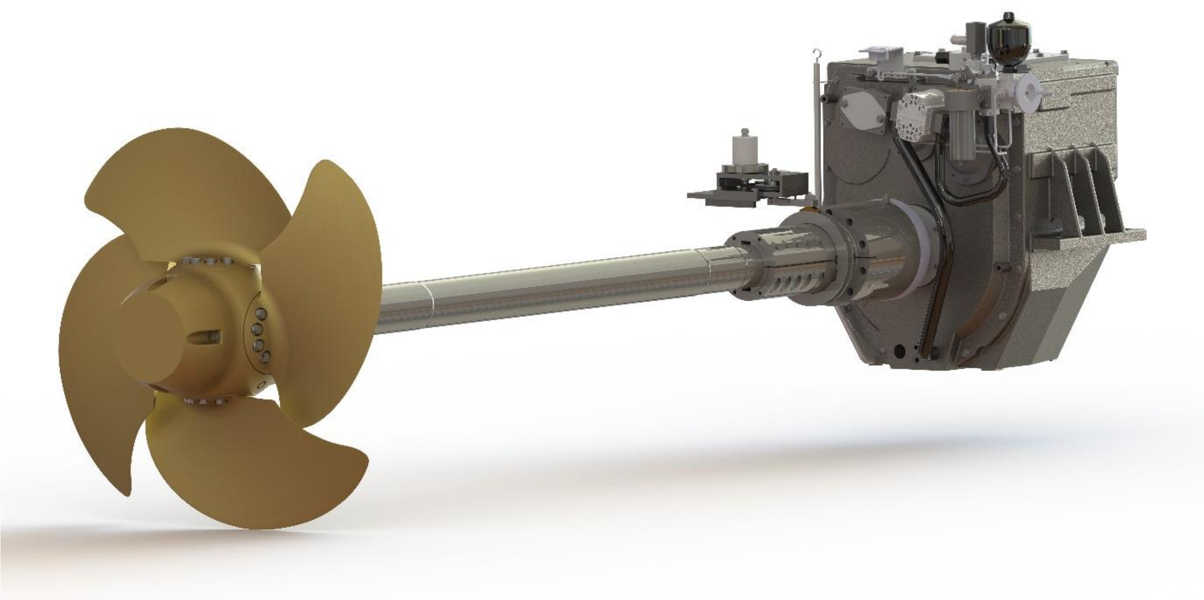

Figure 10: Controllable Pitch Propeller (CPP). [22]

- Better manoeuvrability, in terms of moving from heading to reverse smoothly without having to stop or change the engine direction. As such a non-reversible can be used for both forward and astern operation.
- Higher propulsion efficiency than FPP, thereby optimising speed and bollard pull performance.
- Efficient use of engine power at every situation including during manoeuvring, trawling operation, cruising etc. A change in the speed of vessel can be achieved without changing the engine rotational speed (rpm) in any way.
- CPP can achieve faster response of speed change whenever required as compared the FPP.

The major down side of the CPP is the maintenance cost compare to FPP, it is relatively cheaper and easier to maintain the FPP because it doesn't have any special hub mechanism as the CPP. Also, the initial cost of the CPP is way higher than that of the FPP. But in a nutshell, for this particular vessel design, trading off the cost for higher research efficiency is important consideration, as such, the CPP was selected for the design operational capability of this vessel. Although, the FPP coupled with a bow propeller can also achieve a relatively good stability and manoeuvrability as the CPP, but for such a case, the size of the vessel shall be taken into consideration also. In this study, for a vessel that is required for high level science research accuracy, the Controllable Pitch Propeller (CPP) shows better suitability characteristic in many ways.

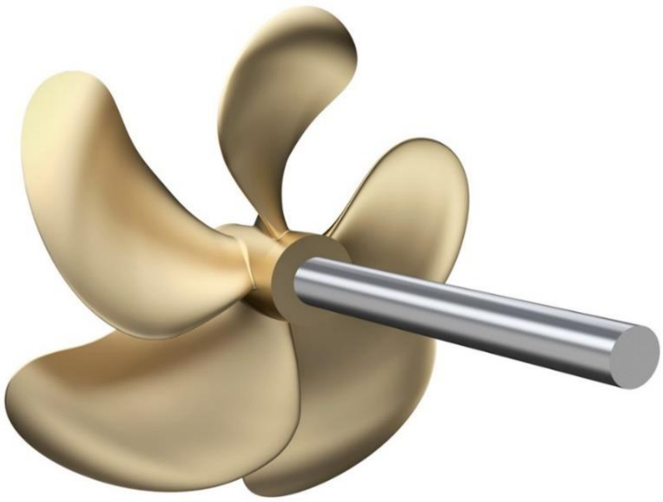

Figure 11: Fixed Pitch Propeller (FPP)

3.4 Main Engine and Auxiliaries Selection

The propulsion power and engine selection is discussed in the next chapter (Chapter 4). But on a general note, the power required is determined by the hull form and total resistance of the hull, and there are lots of marine engines that have been designed to satisfy a wide range of power requirements for different vessels. So in the next chapter, the propulsion power and total resistance of the vessel is calculated and the right range of engine selection shall be based on the result. The auxiliaries also shall be selected based on the inboard power requirement and the redundancy as is discussed in the next chapter.

3.5 Comparing Reference Vessels

Several research vessels have been mentioned and discussed as references throughout this study, and each of the vessels discussed has distinct parameters, operational profiles, classification, operational region or environment and other characteristics that qualifies it to be considered as a vessel of reference for this study. These reference vessel are place side-by-side in tabular form (see Table 9, Table 10, and Table 11 below) so as to compare some of the special features and characteristics to aid in understanding of the influence of certain parameters on their overall performance. Of importance to note from the Table 9 and Table 10, below is the relationship between the length, power and speed of the vessels. A closer look shows that the bigger the size (length and beam) of the vessel, the more power it requires. Looking at R/V Callista and R/V Geomari from the tables 9 and 10, their lengths are 19.75m and 20.0m and the corresponding main engines power are 650hp and 700hp respectively. On the other hand, the R/V Coastal Explorer and R/V Gulf Surveyor has lengths of 16.5 and 14.6 respectively, and corresponding main engine power of 450hp and 247hp respectively. This therefore shows that the power requirement largely depends on the size of the vessel.

Table 9: Comparing Main Dimension and Performance of reference vessels

Vessels	**R/V Callista**	**R/V Coastal Explorer**	**R/V Golf Surveyor**	**R/V Geomari**
Length (m)	19.75	16.5	14.6	20.0
Beam (m)	7.40	5.5	5.2	7.6
Draught (m)	1.80	*	1.4	0.9
Gross Tonnage (t)	50	*	*	75
Max/Cruise Speed (kt)	14/10-12	High speed*	18/14	*/20
Capacity	36 passengers	*	18 passengers	*
Range (nm)	400	*	*	300

Note: potions mark (*) implies that information is note given or not available.

Also, the Table 11 compares other relevant criteria of importance in selection of work/research vessels. As can be seen from the table, all the vessels in consideration are Catamaran, also, they are all made of Aluminium material, these are largely due to the advantages the Catamaran possesses over other hull forms, and also the benefits of Aluminium over other materials (see details in section 3.2 above). The table 11 also shows that these reference vessels area designed are built in the recent decade (between 2003 and 2015), as such, the material and other design selection criteria for these vessels are of latest technologies and advanced development. The Table 11 also shows that two of the vessels (including Geomari and Callista) are built by Finnish companies, and the R/V Callista was highly praised for its quality and efficiency in performance by the owner (University of Southampton) as it is operating at optimum satisfaction as described by Gary Fisher (Physical oceanographer at National Oceanography Center, Southampton).

Table 10: Comparing Power and Propulsion of reference vessels

Vessels	Engine	Propeller	Power
R/V Callista	Twin 650hp Scania D12 Marine diesel engine	890mm Radice S4 bronze propeller	240V AC throughout, 415V, 32A 3phase x1 socket (rear deck)
R/V Coastal Explorer	Twin 6.7L 450hp FPT Diesels	(2) 4 blade propellers	12VDC system, 50 amp shore power line and Northern Lights diesel generator 20kW
R/V Gulf Surveyor	2 x Cummins QSB 6.7L, 184kW (247hp) @2600rpm	(2) fixed 5-blade propellers	120/240V AC, 21.5 kW Cummins Onan marine generator
R/V Geomari	Dual 700hp (522 kW) Caterpillar Diesel Engines	A waterjet propulsion system	*

Table 11: Comparing reference Vessels on other Criteria

Vessels	R/V Callista	R/V Coastal Explorer	R/V Golf Surveyor	R/V Geomari
Hull form	Catamaran	Catamaran	Catamaran	Catamaran
Material	Aluminium	Aluminium	Aluminium	Aluminium
Year of Manufacture	2006	2013	2015	2003
Manufacturer	Tyovenne Oy	Armstrong Marine Inc.	All American Marine Inc.	Mobimar Oy

The Table 10 above compares the power and propulsion of these reference vessels including RV Calista, RV Coastal Explorer, RV Gulf Surveyor and RV Geomari, while Table 11 compares other criteria of the vessels as is relevant to these study. The criteria in consideration in these table are those of key significance to this study at this level, subsequent studies if necessary may consider more critically other detailed criteria.

4.0 CONCEPT DESIGN

The concept design results from the selection of suitable basic components and parameters combinations based on initial specifications from vessel owners, the mission requirements, and environmental legislations, put together to form an optimum concept of research vessel. The study of the different reference vessels and comparing of the same vessels gave rise to what the prospective vessel should look like considering the purpose and environment. Also, the concept considers some basic technical calculations with respect to the main dimension, the power and speed so as to understand and ascertain that the selected parameters and criteria actually satisfy certain fundamentals of research vessels design. The design economics including the cost effectiveness and viability of the vessel is also accounted for at this stage.

4.1 Preliminary Design

The design at this stage focuses more on the Economic factors rather than environmental factors that influence any design, and in this case, the main economic drivers include the construction cost, speed, and in particular operational cost. For a new design, the required power estimate influences virtually every other aspect of the design and it is obtained by comparing with existing similar vessel or from a model test [23]. For this design stage, the power design was obtained by comparing with existing similar vessel design including R/V Callista [9], and R/V coastal explorer [14], even though in calculating the power for propulsion, the resistance needed to be calculated with a high degree of accuracy such that the propulsive power can be predicted with an estimate of the uncertainties of the result. For effective design, an estimation of the power required was determined using Holtrop's approximate power prediction method [24]. The following steps were taken to arrive at desired result:

i. Determination of the open water resistance and power prediction
ii. Determination of mass and cost of installed machinery.

4.1.1 Hull Design

Main Dimensions and Definitions

The main dimensions are some of the key parameters taken into consideration at this start point because they are used to determine the total resistance of the vessel which in turn determine a chain of other criteria. As such, the following parameters as presented in Table 12 below are used in calculation procedure for the Vessel Total Resistance (R_T):

Table 12: Hull design Parameters

L	Length
B	Beam
T	Draught
L_e	Length of entrance
L_m	Length of Parallel midship
α	Waterline angle
φ	Stem angle
ψ	Flare angle normal to the hull surface
ρ	Density of water (Baltic Sea water 1005kg/m3)
∇	Displacement of the hull
m	Mass of displacement
S	Wetted surface of the hull
L_{wl}	Length of waterline
V_{OW}	Open water speed
C_P	Prismatic coefficient
L_{Cb}	Longitudinal centre of buoyancy forward of $L_{wl}/2$
F_n	Froude number
R_e	Reynolds number
C_w	Waterplane area coefficient

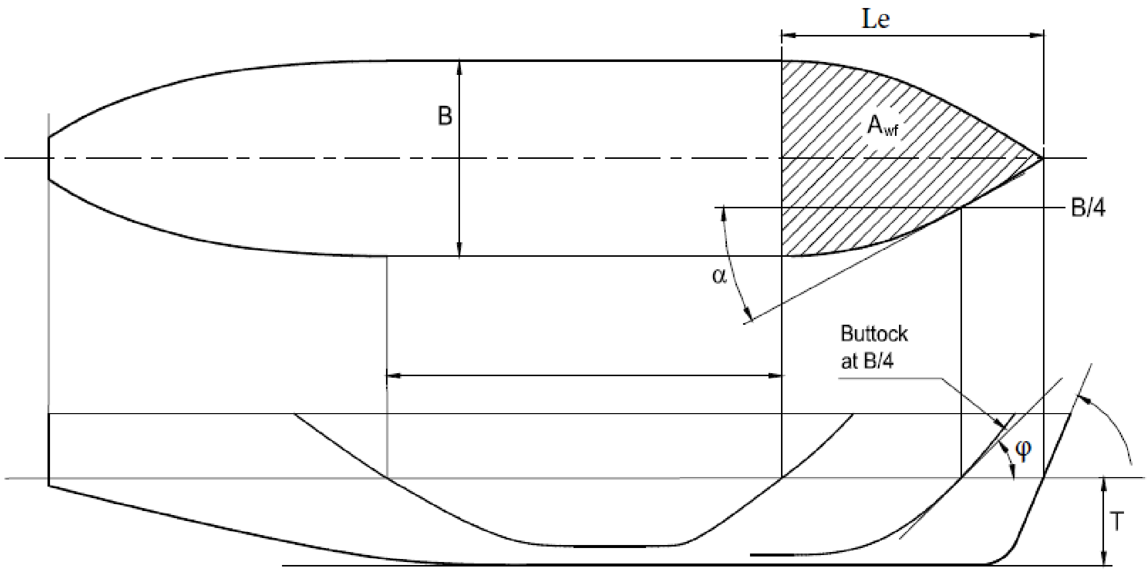

Figure 12. Determination of Geometric quantities of hull. [25]

Fixed values

Design values are given as per design specifications and requirement include

$L, B, T,$

Calculated Values from the design values and using approximations

$\nabla,\ L_e,\ L_m, C_P, C_W, S, F_n, R_{e,}$

Environmental constants and other variable include; ρ, Vow,

4.1.2 Determination of Propulsion Power

Propulsion Power Design

The cost of propulsion varies with the propulsion power required for different operations and different hull design. In order to determine a cost-effective propulsion for this study, it is therefore of utmost importance to determine the power required for different vessel design in various operational conditions.

Power Required for Single Hull (Monohull)

The open water resistance according to Holtrop [24] is given by the expression:

$$R_T = R_F(1 + k_1) + R_{APP} + R_W + R_B + R_{TR} + R_A \quad (1.0)$$

The frictional resistance according to ITTC-1957 friction formula is given thus

$$R_F = 0.5\, \rho\, V_{ow}^2\, S\, C_F \tag{1.1}$$

The resistance of appendage is given determined by the expression

$$R_{APP} = 0.5\rho\, V_{ow}^2\, S_{APP}(1 + k_2)_{eq}\, C_F \tag{1.2}$$

For the wave-making and wave-breaking resistance, it is given by the expression

$$R_w = c_1 c_2 c_5 \nabla \rho g\, \exp\{m_1 F_n^d + m_2 \cos(\lambda F_n^{-2})\} \tag{1.3}$$

The additional pressure resistance of bulbous bow near the water surface is given thus

$$R_B = 0.11\, \exp(-3P_B^{-2})\, F_{ni}^3\, A_{BT}^{1.5}\, \rho g/(1 + F_{ni}^2) \tag{1.4}$$

An additional pressure resistance of immersed transom stern is given by the expression

$$R_{TR} = 0.5\rho\, V^2 A_T c_6 \tag{1.5}$$

The model-ship correlation resistance is given thus

$$R_A = \frac{1}{2}\rho\, V^2\, S\, C_A \tag{1.6}$$

$$C_F = \frac{0.075}{(Log_{10}Re - 2)^2} \tag{1.7}$$

$$\nabla = L_m \times B \times T + \left(L_e \times B \times \frac{T}{3}\right) \tag{1.8}$$

Determining the total resistance for this study case, R_{APP} is not required, and the values of the resistance $R_{TR} = 0$, $R_B = 0$

Hull	$L = 18\, m$ $B = 8\, m$ $T = 1.2\, m$
Bow Angles	$\varphi = 19^o$ $\alpha = 23^o$
Other Parameters	$\rho = 1005\ \mathrm{Kg}/m^3$ $L_e = 5m,\ L_m = 11m$ $m = \nabla \times 1005$ $V_{ow} = 16 \times 0.5144\, m/s$
Total Resistance	$\boldsymbol{R_T = 22.410\ kN}$
Effective power for open water	$\boldsymbol{P_1 = 184.440\ kW}$

But the effective cruising power in open water is given by the expression

$$P_1 = R_T \times V_{ow} \qquad (2.0)$$

Table 13: Power Required for Single Hull (Monohull)

Power Required for Double Hulls (Catamaran)

The resistance for multiple hulls is simply given as total resistance multiply by the number of hulls. Thus for catamaran, it is given as;

$$R_{T2} = 2 \times \{R_F(1 + k_1) + R_{APP} + R_W + R_B + R_{TR} + R_A\} \qquad (3.0)$$

$$\boldsymbol{P_2 = R_{T2} \times V_{ow}} \qquad (4.0)$$

Service Allowance of Vessel

Depending on the service area, the service allowance helps to determine the installed engine power, taking into account the weather condition as may be expected on vessel trade route. According to the suggestion by Harvald [26], the average service allowance in percentage for the Europe-Australia and Europe-East Asia are suggested to be 20-25%. [27] For more accurate prediction of the installed Engine Power (P_E), the service allowance needed is given thus;

$$\boldsymbol{P_E = R_{T2} \times V_{ow} \times \left(1 + \frac{\textit{Service allowance}\,\%}{100}\right)} \qquad \textbf{(5.0)}$$

Therefore the effective engine power required for steady cruise mode in open water for this design is given as in the Table 14

Table 14: Power Required for Double Hulls (Catamaran)

Resistance for multiple hulls	$\boldsymbol{R_{T2} = 44.820\ kN}$
Power for double hull	$\boldsymbol{P_2 = 368.880\ kW}$
Effective engine power required	$\boldsymbol{P_E = 461.100\ kW}$
Actual Power required	$\boldsymbol{P = 750\ kW}$

Other service power consumables

To establish an accurate design power required for any vessel, depending on the predefined function, operational scope and environment, a knowledge of other basic inboard power consumable is necessary. For the purpose of this design, some of the basic inboard power consuming devices can be seen as presented in the Table 15 below. The actual (total) inboard power consumption is not limited to the equipment as listed in Table 15, rather this is just a concept selection, as the detailed equipment selection will highlight other equipment as may be necessary.

Table 15: Onboard Power Consumption

S/N	DEVICE	QUANTITY	UNIT PC (kW)	TOTAL PC (kW)
1	Onboard Computers [28]	4	0.25	1
2	25” Display Unit	6	0.15	0.9
3	Onboard Lightings	1	2.5	2.5
4	Marine AC unit with heating core	2	20	40
5	Norcold Marine built-in Refrigerator	2	0.4	0.8
6	Table-top Microwave	1	1.5	1.5
7	Onboard Power outlets	10	0.24	2.4
8	Coffee Machine	1	1.5	1.5
9	Marine Stove	1	2	2
10	Water Pump	2	1.2	2.4
11	Others (Miscellaneous)	1	40	40
12	**Total Power Consumption (PC)**			**95**

$$\boldsymbol{P_C = 100\ kW}$$

<u>*Design Power*</u>

The design power is the sum of all the known and unknown power required to effectively drive all installed machinery and onboard appliances.

$$\boldsymbol{P = P_E + P_C + P_O} \qquad \textbf{(6.0)}$$

P_O Is the other unknown (miscellaneous) power consumptions. Therefore, the Actual safe working power required for the design within the required specification is chosen to be as in Table 14.

4.2 Power Vs Speed Design

The design dimensions, power and speed requirement was based on the reference vessels as contained in chapter 2 above and also the calculations as contained in section 4.1 above. The reference vessels considered include; R/V Callista, R/V Coastal Explorer, R/V Gulf Surveyor and R/V Geomari. From the technical data made available for these reference vessels as contained in the Appendices A, B, C, & D, they have length overall (LOA) between 14.00 to 20.00 metres, Beam between 4.00 to 7.90 meters and Draught between 0.80 to 1.80 meters. As such, the design speed and power required was calculated and optimised based of the dimension ranges of the preselected reference vessels.

4.2.1 Power Vs Speed design for Catamaran

To move a vessel through water body requires first to overcome the force that tends to oppose the motion of the vessel, this force as it is acts in the direction opposite to the direction of the movement of the vessel and it is refer to as the resistance of the vessel.

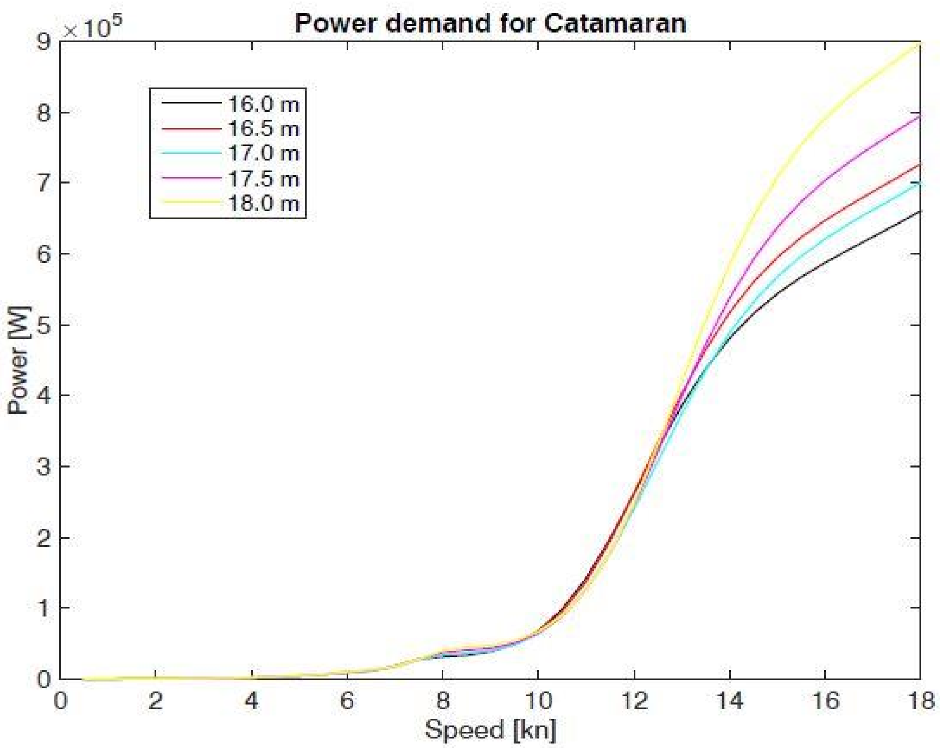

Figure 13: Power Vs Speed demand for Catamaran. [29]

As established in the power prediction method by Holtrop, the key parameter in determining the power required for any vessel is the resistance of the vessel which is determined from the hull form. The catamaran is a twin-hull vessel, having virtually twice the resistance characteristics of a single-hulled (monohull) vessels as can be seen in section 4.1.2. Therefore, if the resistance of a catamaran vessel is twice that of a monohull with the same hull form, therefore the power require for certain speed is equally influenced by the number of hulls.

4.2.2 Power demand for Catamaran in Open Water

There are different resistance predictions used in estimating the resistance of a hull in open water, and different hull forms has different methods suitable for predicting the resistance in open water. As such, the approximate power prediction method by Holtrop was used in this case to determine the open water resistance for the vessel.

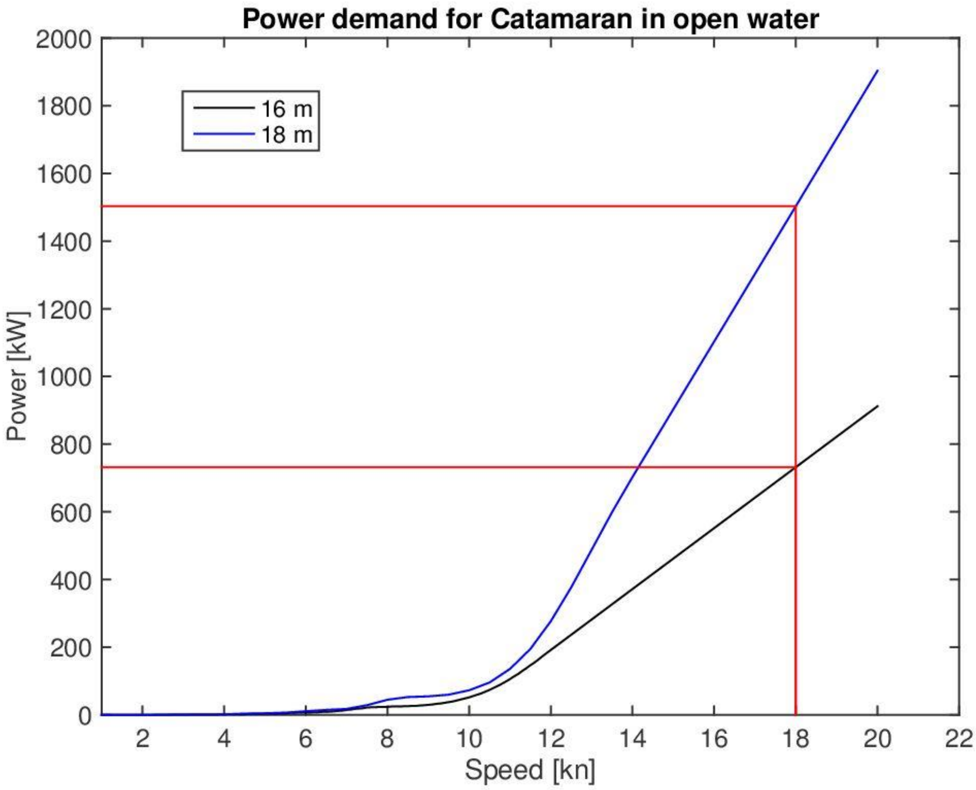

Figure 14: Power Demand for Catamaran in Open Water

4.2.3 Power demand for Catamaran in Ice

The Power Vs Speed required for this future coastal research vessels was determined with consideration of the reference operation environment. The Baltic Sea and the Finnish archipelago as discussed in chapter one is characterised by longer winter than summer making it to experience a longer period of ice build-ups. The build-up of ice along the Finnish archipelagos extends beyond the winter into the spring and sometimes to the later part of it. Although, the ice build-up during the spring period is usually of thin layer, ranging from about

5cm to 10cm (0.005m to 0.010m), research activities and other study explorations can be hindered for vessels that are not design to operate in any ice conditions. This therefore formed one of the basic characteristics for vessels suitable for environments and regions with such characteristics as the Finnish archipelagos. In designing for the TZS vessel, the power vs speed requirement was calculated both for the open water and ice condition. The Figure 14 above shows the power requirement with respect to speed for catamaran in open water calculated using Holtrop method. [29]. Likewise, the Figure 15 shows the power required for Catamaran to go in ice of 10 cm and 20 cm respective. This is considering the maximum level of ice formation along the coast of the Gulf of Finland outside the winter season.

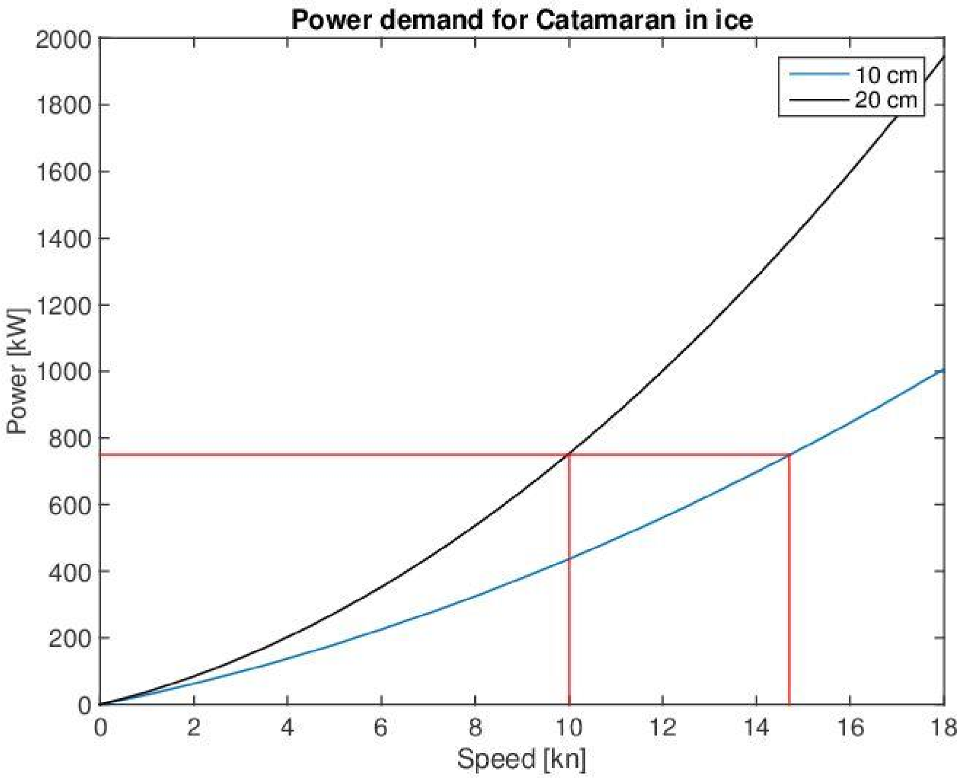

Figure 15: Power demand for Catamaran in Ice. [30]

Applying the Finnish-Swedish Ice Class Rules (FSICR) to a vessel that falls outside the validity range established by the design rule is quite difficult, but for the vessel to be able to operate in the thinnest layer of ice, it should satisfy certain criteria both within and outside the scope of the rules. According to Antti Immonen of Mobimar, designing a small workboat to navigate through a thin layer of ice (of about 10 cm) requires using the right materials (either steel or aluminium) and strengthening the region of the hull. [31]

There have been several analytical and empirical approaches proposed for the calculation of resistance of vessel in ice. Lindqvist presented a relatively simple empirical formula that considers the hull form, ice thickness, ice strength and friction as the main particulars in calculating of vessel's resistance in ice. In his formula, the ice resistance is divided into three parts, including the crushing, bending and submersion. [32] The equation (7.1) below shows the three components variables on which the Lindqvist's model depends. The Lindqvist's model assumes that the ice resistance increases linearly with speed, this can be seen as show in the Figure 15 above. As such the empirical constants in the velocity term are used to calculate the total ice resistance. The design method considered for this concept is the design for small vessels navigating through ice, as such, the total resistance through ice $\boldsymbol{R_T}$ is taken to be the combination of the open water resistance $\boldsymbol{R_{OW}}$ and the pure ice resistance$\boldsymbol{R_i}$. [33]

$$\boldsymbol{R_T = R_i + R_{OW}} \qquad \textbf{(7.0)}$$

$$\boldsymbol{R_i = f\{R_c + R_b + R_s\}} \qquad \textbf{(7.1)}$$

4.3 Engine Selection

The actual power required to operate the proposed work vessel efficiently with the required parameters as discussed in previous sections, is contained in Table 14 as shown above. There are quite a lot of marine engines that fall into the category of this design power range, but in selecting a suitable engine, the cost effectiveness of operation is taken to be the key consideration. This includes the fuel consumption, the size (dimension and weight) which determines how much space per volume it will occupy and the contribution to the gross tonnage of the vessel. The Table 16 below shows a simple comparison of selected marine engines that suitably fit for this design. The engines compared include the Volvo Penta D9-500, Cummins QSC 8.3 and Scania DI13 092M. These engines have the same power rating of 368 kW (max) and same number of cylinders and configuration (6-inline engine) but vary in terms of other specifications, as such, gives room for choices depending on what criteria is of priority in the consideration of specification. One factor that will determine largely the choice engine from this range will be the cost and alongside the operating economy, seeing that the engines has almost the same performance and size.

Table 16: Comparison of Different Marine Engines

Engine Specifications	**Volvo Penta (D9-500)**	**Scania (DI13 092M)**	**Cummins (QSC 8.3)**
Rated Power (kW)	368 (max)	368 (max)	368 (max)
Rated RPM	2600	1800 (max)	2600
Rated Torque (Nm)	1630 (at 1400)	1952 (at 1800)	1799 (at 1800)
Weight (kg)	1075	1285 (excluding oil and coolant)	896
Dimensions (mm)/LxWxH	1787 x 940 x 1000	1503x974x1174	1422.0 x 977.5 x 981.6
Fuel Consumption (l/h)	95.07	86.0	96.1
Displacement (L)	9.4	12.7	8.3
Cylinders Configuration	6 in-line	6 in-line	6 in-line
Bore/stroke	120/138	130/160 mm	114/135 mm

Volvo Penta (D9-500)

The Volvo Penta D9-500 in-line 6-cylinder, 9.4-liter Marine Diesel Engine is considered to be a good choice for a vessel of the designed specifications and selected criteria. With rated power of 368 kW (500hP), Electronic Vessel Control (EVC) and EPA Tier 3, EU IWW, IMO Nox Tier II emission compliance, a combination of two (Twin) of this is considered suitable for this design. See appendix D.

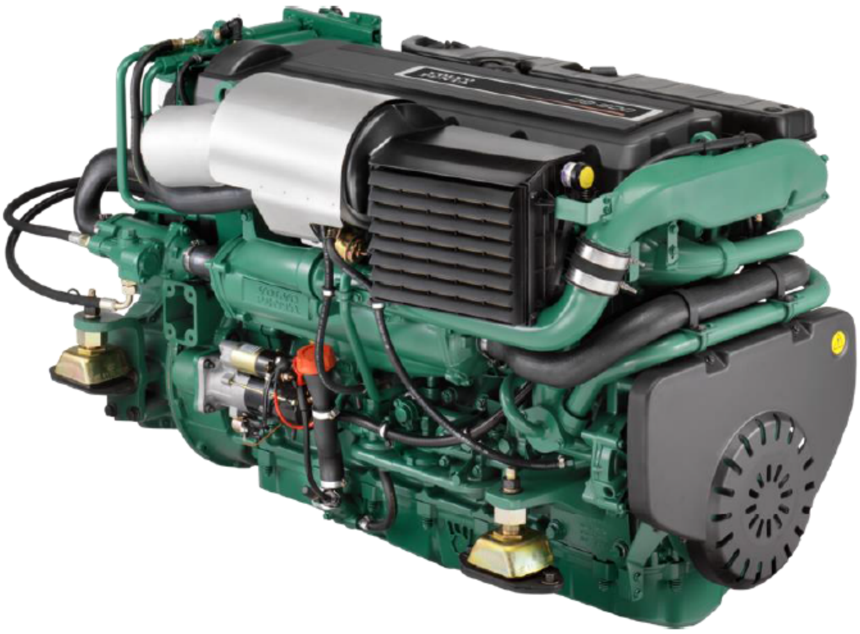

Figure 16: Volvo Penta Inboard Diesel Engine. [40]

Scania (DI13 092M)

The Scania DI13 092M is another very good Marine inboard engine, with rated power of 368 kW, having a relatively better fuel consumption as presented in the Table 16 above, the Scania DI13 092M is considered a very good choice when considerng fuel consumption to size because it is relatively bigger compared to the other on the table. This engine satisfy the classification level of IMO Tier III, IMO Tier II, EU Stage IIIA.

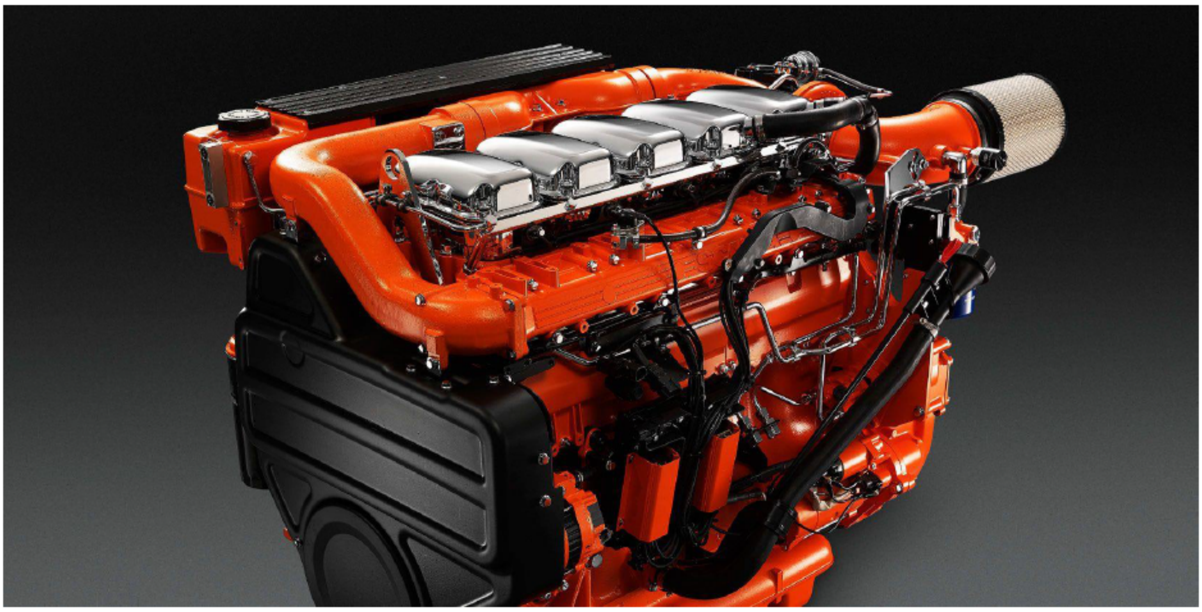

Figure 17: Scania DI13 070M Marine inboard engine

Cummins (QSC 8.3)

The Figure 18 below a picture of the Cummins QSC 8.3 marine diesel propulsion engine, it is a 4-stroke diesel engine with 6-in-line cylinders. Improved fuel economy relative to the Volvo Penta D9-500 as show in the Table 16 above. The Cummins QSC 8.3 has a certification level of Tier 3/stage IIIA, IMO Tier II and RCD 1. [34] With rated power of 368 kW, and weighing a little below 1000 kg, the Cummins is positioned at better advantage for this design requirement.

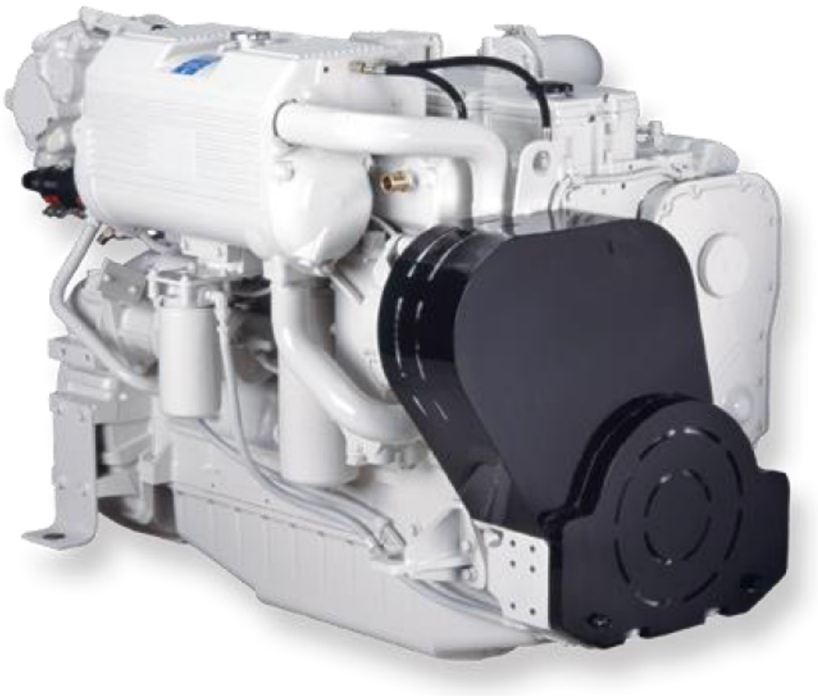

Figure 18: Cummins QSC 8.3 Marine Diesel Propulsion Engine

4.4 Determination of Production Cost

The cost of a vessel is largely dependent on the individual cost of the installed machinery and the production material which are both functions of the specific job requirement of the vessel, the work environment, and operating conditions. Also, of important in cost determination is the size of the vessel. Larger vessels require more materials and man-hour in production. As such, determining cost at this stage require a robust understanding of what is required of the vessel in terms of material, size, special equipment and machineries. In some cases,, smaller vessels may cost more to produce if it is designed for some special purpose, for instance, a naval vessel requires for special operation may require certain level of detailed security consideration in design, so also it is with science research vessels, the nature of the operation determines the level of design details require and equipment installation.

4.4.1 Material Selection

Many factors are taken into consideration when selecting material meant for manufacturing of work boat. Most important of them are the cost, nature of operation that is required of the vessel and the environment in which the vessel is meant to operate. Except for special vessels with special requirements, Material selection in marine design is largely dependent on the operational environment and the predefined functions. Taking the reference environment of operation into account, the marine environment possesses a lot of characteristics that makes it difficult for a wide range of materials to survive long enough when exposed in their natural form except with some level of treatment and conditioning. Corrosion, temperature, wave and wind-speed are the most important conditions to consider in selecting materials for such environmental operations. For the purpose of this design, the material consideration is limited to the following:

- Aluminium Alloy 5086 (20mm sheet) marine grade [35]
- ABS/DNV Steel Plate grade “A” (5mm) –Shipbuilding/Marine steel plate [36]

The body cost (which largely comprise of the hull and superstructure), therefore, is largely dependent on material, size, and design. For cost effectiveness without compromise in safety and material standards, size optimisation can be used to achieve a cost effective design.

4.4.2 Material Cost

The cost of material is one that is never fixed, this fluctuates largely with the slightest economic perturbation. Also the prices of material varies at different market across the globe, but this difference is not considered too significant to affect the design at this stage. Taken the universal standard as presented as selected online stores, the costs of the two major materials of choice (Aluminium alloy 5086 plate and ABS Grade A steel plate) are analysed.

Aluminium Alloy 5086 (20mm plate)

Alloy 5086 Aluminium plates are very good marine/shipbuilding material with strong corrosion resistance characteristics. Although sensitive to high temperature of over 200 degrees, they tend to exhibit good characteristics at very low (sub-zero) temperature by gaining strength [37].

ABS Grade "A" Steel Plate

ABS "grade A" marine steel plates are very good shipbuilding engineering material used in manufacturing hulls and other marine structural installations. It has good toughness properties and higher strength, strong corrosion-resistance, good processing and welding properties.

Table 17: Material Cost Estimation

Material	Aluminium (Alloy 5086)
Price/ton	\$1804.00 per ton according to London Metal Exchange [38]
Volume	• Hull size: $V_{Hull} = \{(16 \times 6 \times 2.7 - 15.98 \times 5.98 \times 2.68) - (16 \times 2.4 \times 1.7 - 15.98 \times 2.38 \times 1.68)\} = 1.713\ m^3$ • Bottom Cabin size: $V_{bottom} = \{(6.5 \times 4.5 \times 2.5) - (6.48 \times 4.48 \times 2.48)\} = 1.130\ m^3$ • Top Cabin: $V_{Top} = \{(4.5 \times 4.5 \times 2.5) - (4.48 \times 4.48 \times 2.48)\} = 0.850\ m^3$ Total volume: $V_{Total} = V_{Hull} + V_{bottom} + V_{Top} = 3.693\ m^3$
Mass	Total Mass of the body (M_{body}) is given by the density of Aluminium (ρ_{Al}) multiply by the total volume (V_{Total}): $M_{body} = (2700 \times 3.693) = 9971.10Kg$ Mass of body is given as $M_{body} = 10tons$
Cost	The cost of body (C_b) is, therefore: $\boldsymbol{C_b = \$18,040.00}$ (**€16,255.00**)

4.4.3 Propulsion Power Cost

The power required for the main engine can be deduced from Figure 13 and Figure 15 above. The information as presented on the graphs of Figures 10 and 11 are sufficient to tell how much power is needed for the engine, and as such, the size of engine to be selected. One major driver asides the power requirement is the cost and environment impact (and regulations). For overall propulsion power of about 650Kwatt, the estimated cost of a propulsion engine between 250Kwatt to 400Kwatt as given by Mobimar [31] is within the range €40,000.00 to

€80,000.00. Therefore, for a twin engine of average power rating 320kwatt, the average cost is given as in Table 18.

4.4.4 Propulsion Thrust Cost

For the Controllable Pitch Propeller, the price varies with size in terms of diameter. For a 0.5 to 2m diameter size CPP, the average price ranges from $10,000.00 to $50,000.00.

Table 18: Propulsion Components

Component	Price (€)
Main Engine	$\boldsymbol{C_{Engine} = (2 \times 70{,}000) = €140{,}000.00}$
Propeller	$C_{Proller} = (2 \times 18{,}500) = \mathbf{€37{,}000.00}$ ($40,000.00)

4.4.5 Other Onboard Installations and cost

Based on the design specifications and the operation requirements of the vessel, a collection of carefully selected equipment and machineries are recommended for installation in order that the vessel will meet the need. Considering also that it is a concept designed for now and the soon to come future, every equipment and machinery is flexible for upgrade as maybe needed. This defines the flexibility of the work platform of the vessel, depending on the operational or environmental requirements, these equipment can be easily changed to suit the demand at any given time.

The Table 19 below shows the list of machineries and equipment necessary for smooth and efficient operation of the proposed vessel. These doesn't represent the detailed machinery and equipment but just a basic requirement and to serve as a guide for economic purpose, as many more can be added for optimum operation, especially in the deck area, as it has enough work space that can be used for group field exercises and as well equipped with more machineries for enhanced efficiency of space.

Table 19: List of Installed Machinery, quantity and cost

S/N	Item	Qty	Unit price (€)	Price (€)
A	**DECK**			
	1 ton Knuckle-boom Crane with remote control	1	20,000.00	20,000.00
	2.5 tons Stern A-frame and winch	1	-	-
B	**NAVIGATION**			
	Transas mini ECDIS Navigation System	1	-	-
	Marine Night visibility (IR D-Series D2 driving pair)	1	6,000.00	6,000.00
C	**CABIN**			
	Marine Stove	1	1000	1000
	Norcold Marine Built-in Refrigerator	1	1400	1400
	Table-top micro wave	1	600	600
D	**SAFETY**			
	UMM Certified First Aid Kit	1	500.00	500.00
	32 person life raft	1	5000.00	5000.00
	Smoke Detectors	2	125.00	250.00
	Type "B" Fire Extinguisher	2	100.00	200.00
E	**MACHINERY**			
	Volvo Penta inboard Diesel (D9-500) 368kw	2	70,000.00	140,000.00
	Controllable Pitch Propeller	2	18,500.00	37,000.00
F	**OTHERS**			
	Fresh Water pump	1	-	-
	Marine water pump	1	-	-
	500 Litres Water Tanks (Fresh, Marine and Waste Water)	3	-	-
	4000 litres Fuel Tank	1	-	-
	Marine Stove	1	1000	1000
	Norcold Marine Built-in Refrigerator	1	1400	1400
	Table-top micro wave	1	600	600

4.5 General Arrangement (GA)

The general arrangement of the vessel was based on the requirement and specifications imposed by the predefined operational features, and because it is a design that incorporate the future of scientific research and educational activities, the GA be designed to incorporate a wide range of operational capabilities that will be necessary to facilitate smooth and effective operations in every situation as may be required.

The proposed vessel has three decks, including the Bridge deck, which provides sufficient space for the control and navigation equipment, the Cabin and Lab; which provides work spaces both for the wet and dry labs activities and a cabin space with 2 berth that provide ample space for crew to rest. This also include a dive platform at the aft, and an open work area with multipurpose moon pool. The Machinery deck accommodates the tanks (including the fuel/lubricating oil tanks, fresh water and sewage tanks), the main engines and auxiliaries within the hull.

It is important to note at this point that the general arrangement (GA) is not exactly what it should be, further detailed design is required to reach a proper arrangement of what the actual vessel should be, depending on the need and required usage.

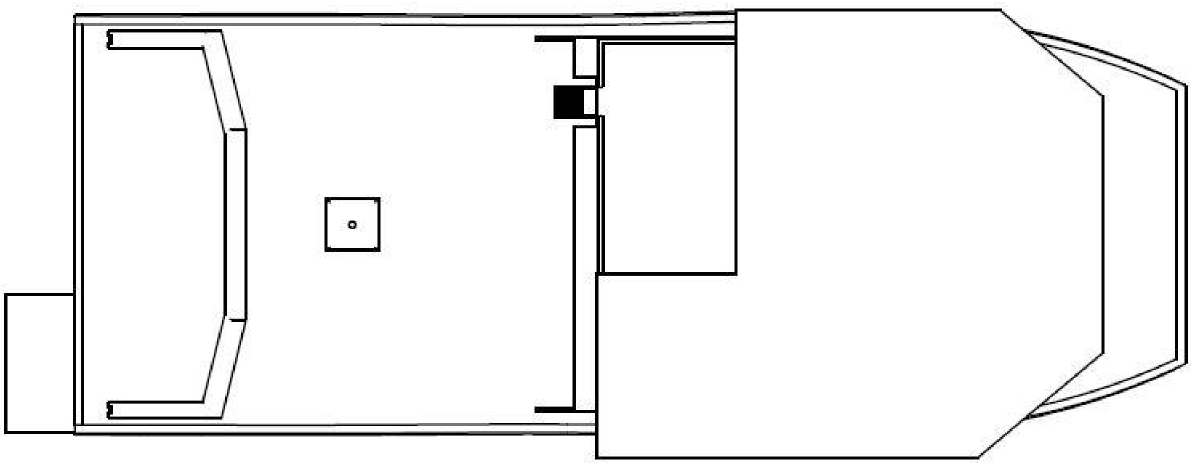

Figure 19: Main deck

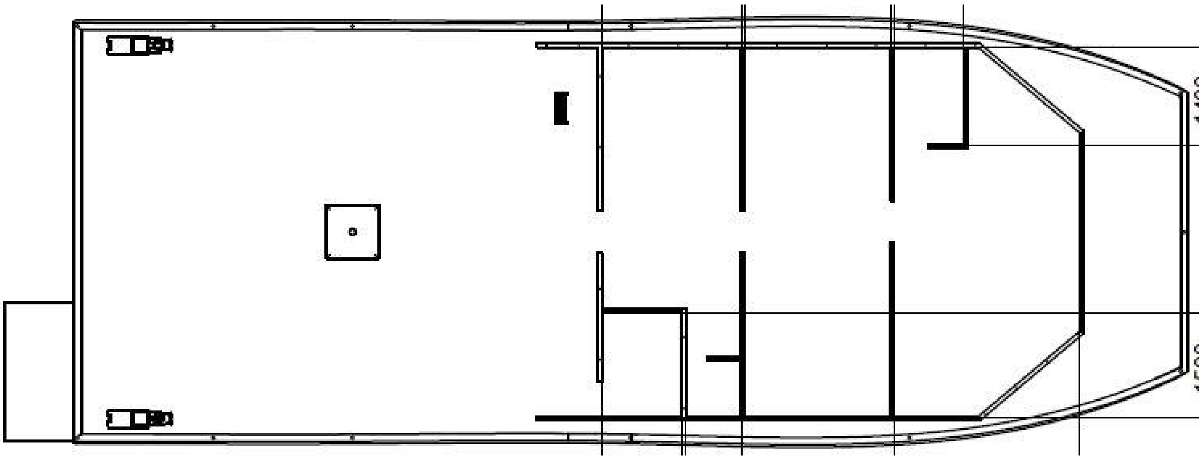

Figure 20: Cabins and Lab area deck

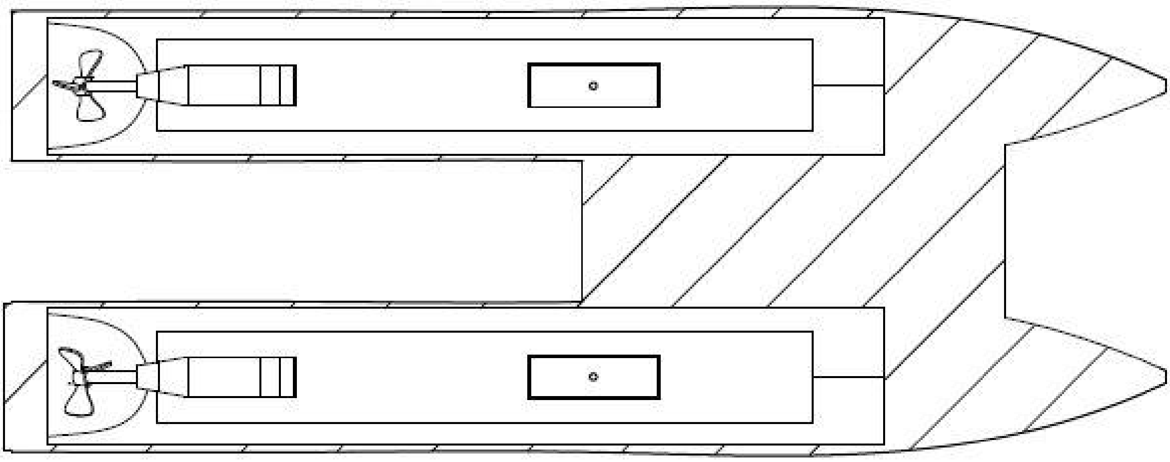

Figure 21: Machinery deck

4.6 Scientific and Operational Features

Considering the fact that the operational scope of the vessel is to meet both the present and future needs of scientific research and educational activity along the Baltic coast and archipelago, the design incorporate modern scientific equipment including a multibeam Echo sounder system for sea bed mapping to full depth, with high resolution and accuracy, Conductivity, Temperature and Depth (CTD) equipment or Rosette which can be deployed through the moon pool, and other bottom sampling equipment like the Plankton nets, bottom grabs, bottom trawls. Depending on the range and nature of scientific research and educational activities, the flexibility of design allow researchers/scientist to take onboard and install other equipment as may be required as time changes.

On the deck, the vessel is installed with an A-frame at the aft for deploying and retrieval (collection) of sampling equipment as may be needed, also about 1 ton hydraulic crane on the starboard side which is controlled both from the bridge and remotely, for lifting and launching of heavy equipment. Hydrographic winches for gathering and collecting of smaller samples.

Within the shelter area are the wet and dry labs for scientific analysis onboard and this work station is directly accessible from the main deck. The wet lab is equipped with a marine refrigerator/freezer for (controlled temperature) storage and preservation of samples for future analysis, a work table/desk and twin sink with both fresh and sea water taps to draw and/or flush water sample and washing/maintaining of sampling equipment. The wet lab is also equipped with a small storage area for other personal equipment as may be required for use in the wet lab. The dry lab area is equipped with computer workstation, desk and other electronics. With up to 6 display units both for individual and group work. Also a storage cupboard for safety wares such as life vest, hard hat and other personal protective equipment (PPE).

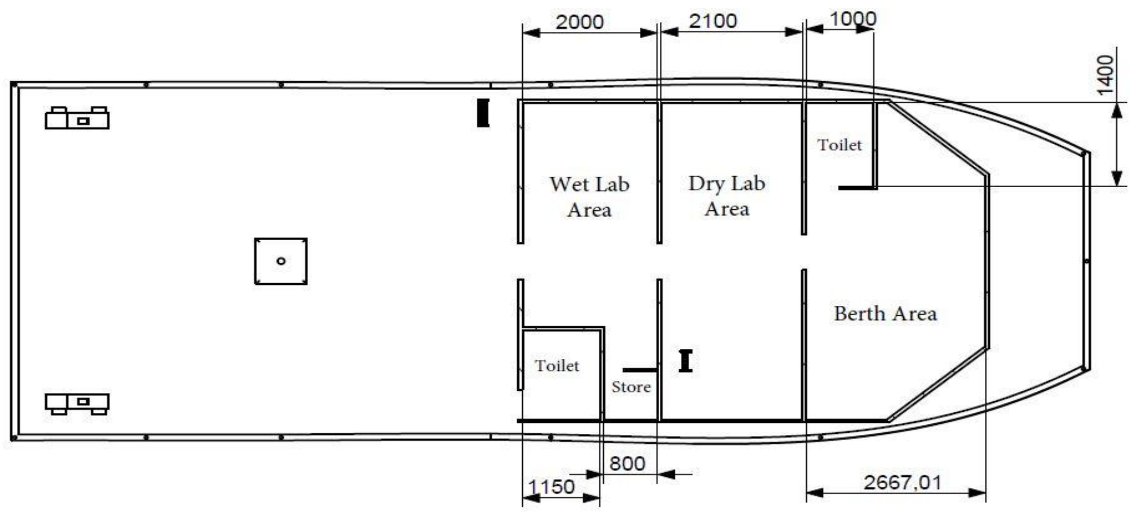

Figure 22: Wet and Dry labs area

5.0 RESULT AND DISCUSSION

From the analysis and calculations presented in the previous chapters; precisely chapters three and four, it has become clear enough to deduce the result as is recommended for this study. Although, cost of material and production experience constant change with time due to the fluctuation of global economy, the result of this finding is meant to be a guide such that as cost changes with time, keeping the concept equation constant, other aspects of the design can be varied to meet immediate needs.

5.1 Selection of Main Dimensions

As discussed in section 3.5 (comparing reference vessels), Table 9 and Table 10 show the relationship between the main dimensions of the vessels and the corresponding power and speed requirements. These is further described graphically in Figure 13 and Figure 15.

The Figure 13 shows the power demand with respect to speed require for Catamaran vessels at different lengths, and as can be seen, the plot is done for vessels of length between 16.0m and 18.0m. From the graph, it is observed that for a length of 16.0m, the power of about 650kW is require for a speed of 18kn. Also, to attain the same speed of 18kn with a 17.0m vessel, a 700kW power is required. And this increases even more for 18.0m vessel at the same speed of 18kn, the required power in this case is about 900kW. This therefore confirms the representations as in the tables 9 and 10 in section 3.5 above. This is similar for Figure 15, more power is required to navigate through different ice thickness at different speeds. The figure shows it that, for ice thickness of 10cm (0.1m), Catamaran vessel will require close to 800kW power to navigate at a speed of about 15kn. At the same power, the same Catamaran vessel can navigate safely through a 2.cm (0.2m) ice thickness at a speed of 10kn. This further shows that, for a higher speed of about 18kn, the vessel will require up to 2000kW to navigate through a 20cm thickness of ice, while less than 1000kW is required to navigate through 10cm of ice thickness at the same speed of 18kn. This therefore summarises the relationships between power and speed at different ice thickness for a Catamaran vessel. As such with this information, it gives the designer the choice to determine the trade-off between power and speed depending on the desired environment and ice condition within operating domain.

5.2 Design Cost Estimation

Based on the design calculations in the previous chapters, the estimated effective cost for building a vessel suitable for research and education with flexible work platform within and along the coast of Finland and archipelago is as presented in the table below.

Table 20: Summary of estimated cost of proposed Vessel

S/N	ITEM	COST (€)
1	Machinery (Engine/Auxiliaries)	160,000.00
2	Deck equipment (2.5 ton A-Frame/1 ton knuckle bum crane) with both remote control and control from the bridge	65,000.00
3	Navigation, Safety and other onboard Science/Education research facilities and installations	600,000.00
4	Material (15 tons of Aluminum alloy 5086 grade, 20mm thickness sheet)	25,000.00
5	Manufacturing cost (+10% for ice strengthening)	850,000.00
6	**TOTAL**	**1,700,000.00**
7	Miscellaneous (+5%)	85,000.00
8	**GRAND TOTAL**	**1,785,000.00**

From the Table 20 above, the approximate estimation for building a flexible scientific and educational work platform that befits the operational conditions and environment as discussed in the previous chapters can be said to be about **One Million, and Eight hundred Euros (€1,800,000.00).** This amount is not taken to be fixed at all time, but as at the time of this research and analysis, it is valid. In view of the cost of the reference vessels and their year of manufacture, the estimated cost of manufacturing a state-of-the-art vessel for such a cost as contained herein, is considered to be within acceptable range for the industry.

Looking backwards, R/V Callista was built in 2005 at an approximate cost of One Million Euros (€1,000,000.00) while Coastal Explorer was built in the year 2012 at the total cost of One Million, Two hundred and Seventy-seven thousand, Five hundred and Twelve Dollars ($1,277,512.00), this is an equivalent of about One Million and One hundred thousand Euros (€1,100,000.00) see detail in appendix B.

5.2 Proposed Specification

From the Power versus Speed Curve presented in Figure 13 and the Power demand in Ice Curve in Figure 15, both under section 4.4, the optimum power and length require for the proposed vessel is obtained. Knowing the required power from the graph using Holtrop's method for approximate power calculation [24], the designed power required was determined. With these information of the vessel length overall, Resistance and designed power, virtually every other Technical specification is determined as presented below. See detail in Appendix A.

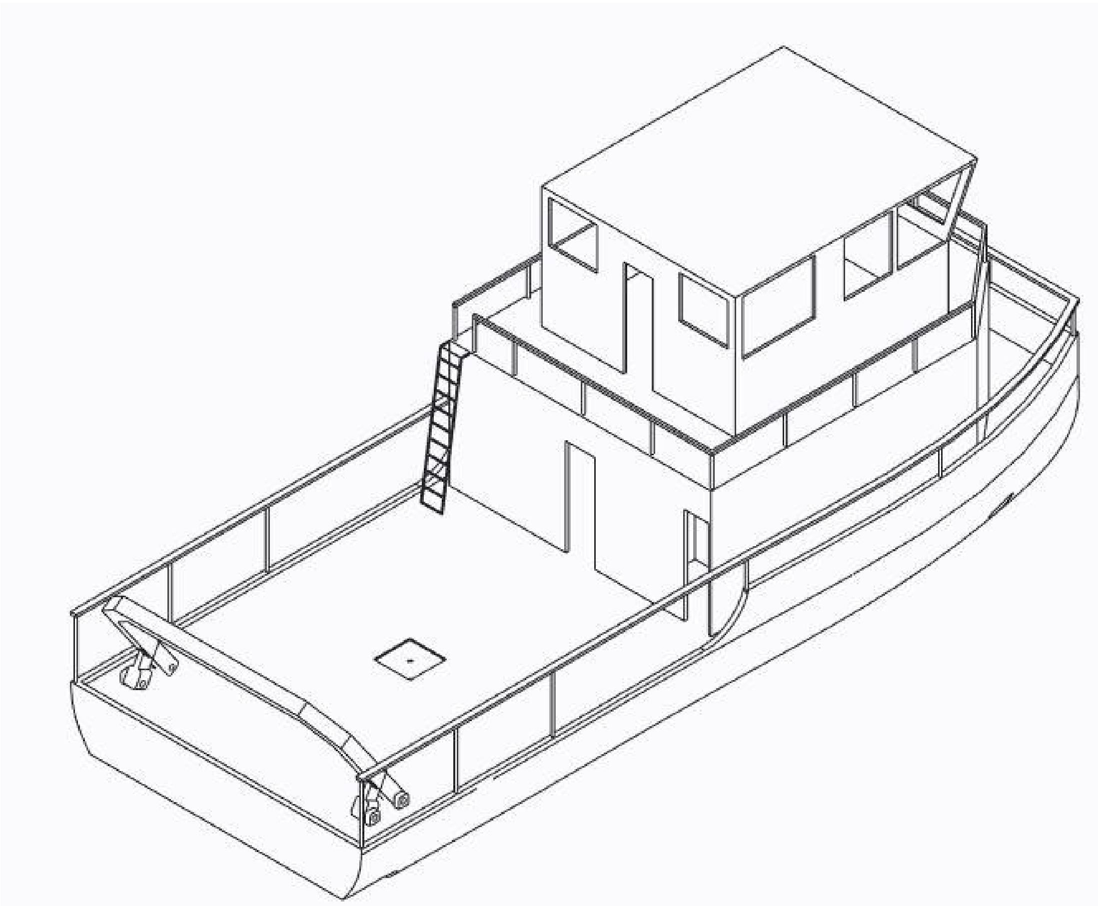

Figure 23: Proposed Research Vessel for TZS

Table 21: Proposed Technical Specification

General	Length Overall: 16.0m Beam: 6.0m Draught: 1.0m Max Speed: 18kn Cruising Speed: 14-16kn
Machineries	Twin (2x) Volvo Penta D9-500, 9.4-liter Marine Diesel Engine in-line 6-cylinder, 368 kW (500hP), 2 x Controllable Pitch Propeller
Deck	Stern A-Frame with Pullmaster Winch (with remote control) – 2.5 tonne, 4.2m max height, 150m cable (3 tonne). Side davit – 100kg Knuckle boom crane – 1.13 tonne @3.5m, 780kg @ 5.3m Engine room hatches and Moonpool Aluminium hand rails for both main and raised decks Diving facilities – kit bench Self-bailing aluminium deck External Stairs from the work deck to the bridge deck Walk-around cabin with raised bridge house.
Main Cabin (Dry Lab)	Interior stairs from dry lab to Raised deck (bridge) Gear/safety equipment locker 4 person settee Computer workstation with storage lockers
Main Cabin (Wet Lab)	Fresh water sink (drains to sewage tank) Sea water flush sink (drains directly overboard) Counter top workstation Marine Built-in cold room The detailed technical specification in contained in the Appendix A.

6.0 CONCLUSION

In conclusion, this designed concept of research vessel is suitable for scientific research and educational purpose along the coast of Finland (the Gulf of Finland) and its archipelagos, but it is not limited to these areas, considering that the references cuts across facilities and vessels from different environment and different regional legislations. This is because the design has taken into account the environmental condition and other data from available vessels operating within the same terrain and others operating in different environments across the globe.

Although this study did not capture all the required details to actually ascertain the exact suitability, but considering the fact that it is a concept stage design, it would be said that the study and findings presented herein are sufficient to inspire further detailed design that will account for the detailed design drawings, classifications and rules regarding environmental and regional legislations alongside other key parameter as may be required.

Important to note is that this study did not involve in-depth design of the hull and other associated component in the design to ascertain the actual suitability for this concept design as this design only involve the analysis of available data form existing vessels, online resources and interview with industry experts. As such it is important to take this into consideration proper detail design for further research.

6.1 Recommendation

For further studies, it is recommended that comprehensive investigation be carried out to ascertain the environmental legislations governing the operational areas of the proposed vessel. Also, the Finland coast of the Baltic Sea is characterised by longer winter compare to summer, with almost year-round thin layer of ice of about 5 to 10 cm covering the water surface (after the summer season). As such the need for reinforcement of vessel hull to meet the requirement. To this regard, it is important investigate and understand the ice classification required and how to interpret this classification for small vessel of the size specified in this design, because that will influence the material selection for the hull and the actual cost may rise.

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APPENDIX

Appendix A: Technical data for the proposed concept design

Proposed Research Vessel for Tvarminne Zoological Station (TZS)

General

Category :	Research & Education
Hull Design :	Catamaran
Material :	Aluminium

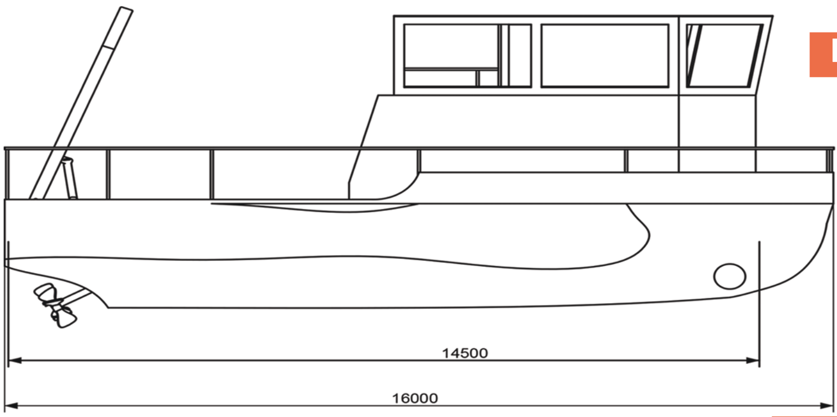
Dimension

Length Overall :	16.0 m
Beam :	6.0 m
Draft :	1.0 m
Deck Area :	10.0 x 5.4 m

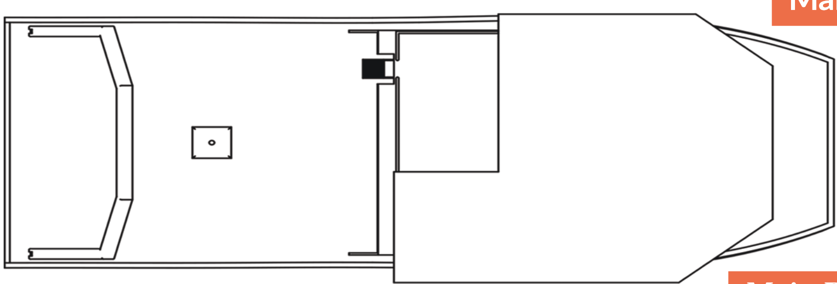
Tank capacity

Fuel :	4000 L
Fresh Water :	500 L
Sewage :	200 L

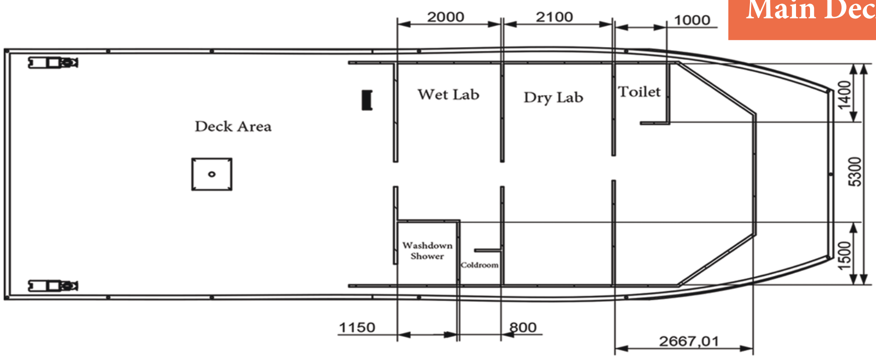
Profile



Main Deck



Main Deck Plan



Accomodation

Cabin :	2 berth
Wet Lab :	3x2m
Dry Lab :	3x4m

Performance

Maximum speed :	18 knots
Cruise speed :	**14-16 Knots**
Fuel consumption :	96L/hr (Rated) 71L/hr (Cruise)

Navigation

GPS :	Transas mini ECDIS Navigation System
Compass :	Magnetic Compass

Safety

1 x 32 Person viking fire Life Raft
32 x Type 1 Adult PFD
3 x Type 1 Child PFD
2 x 30" life ring
30m Rescue Mate throw rope

Manoeuvring and Propulsion

Main Engines :	2 x Volvo Penta Inboard Diesel (D9-500) 368 KW
Propulsion :	2 x Controllable Pitch Propellers

Deck and Lifting Equipment

Deck Crane :	Knuckle Boom Crane -1ton
A-Frame :	Pullmaster PL5 winch (remote control at at a t steering console)

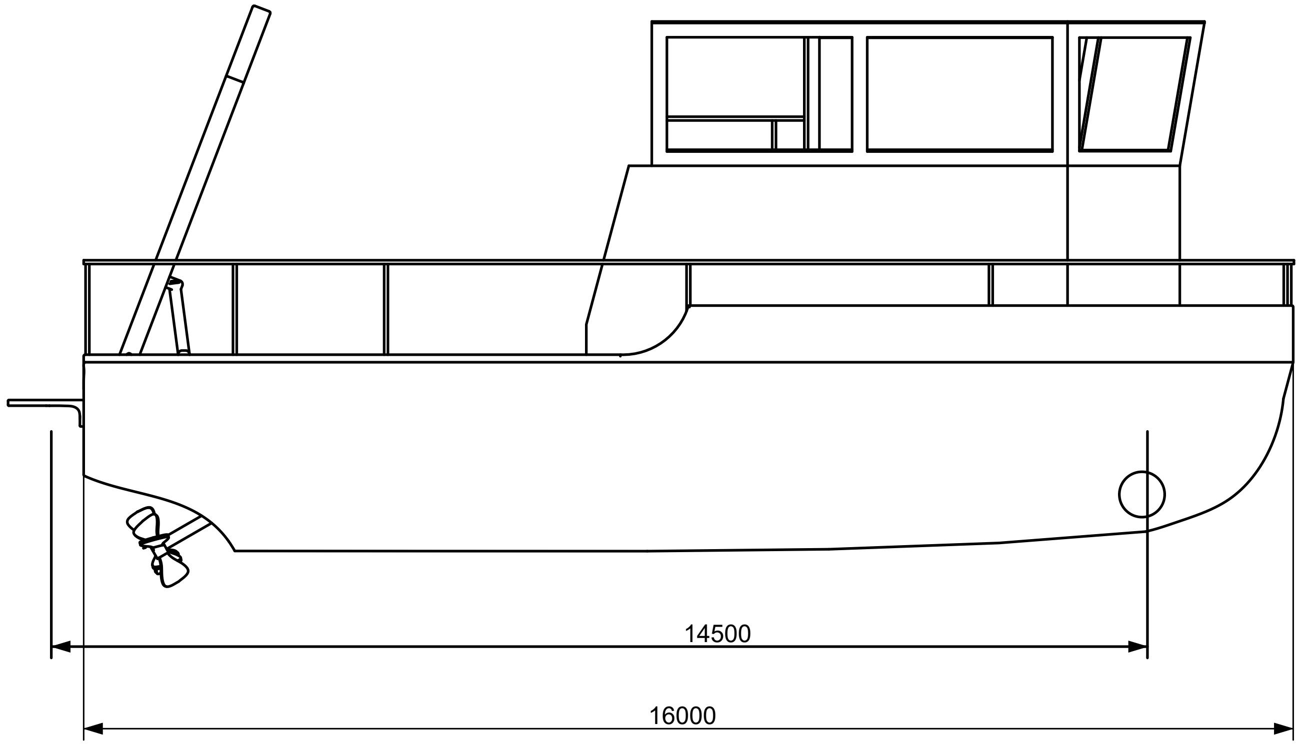
Further Enquiries

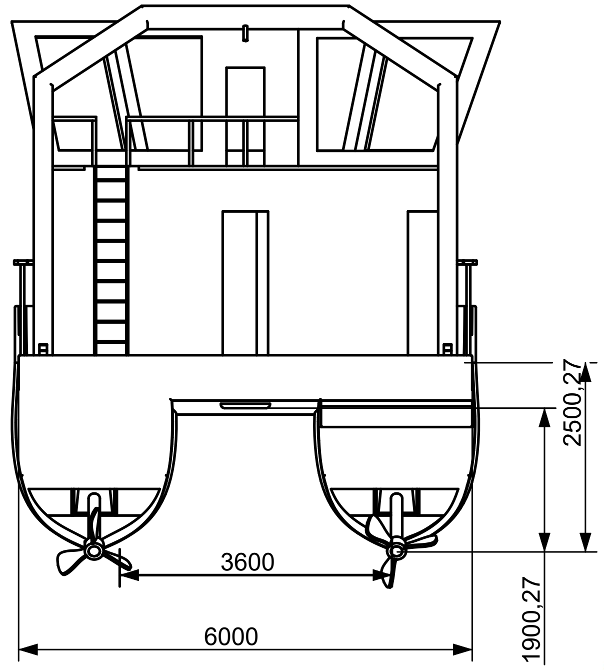
Alf Norkko
(Contact Person)

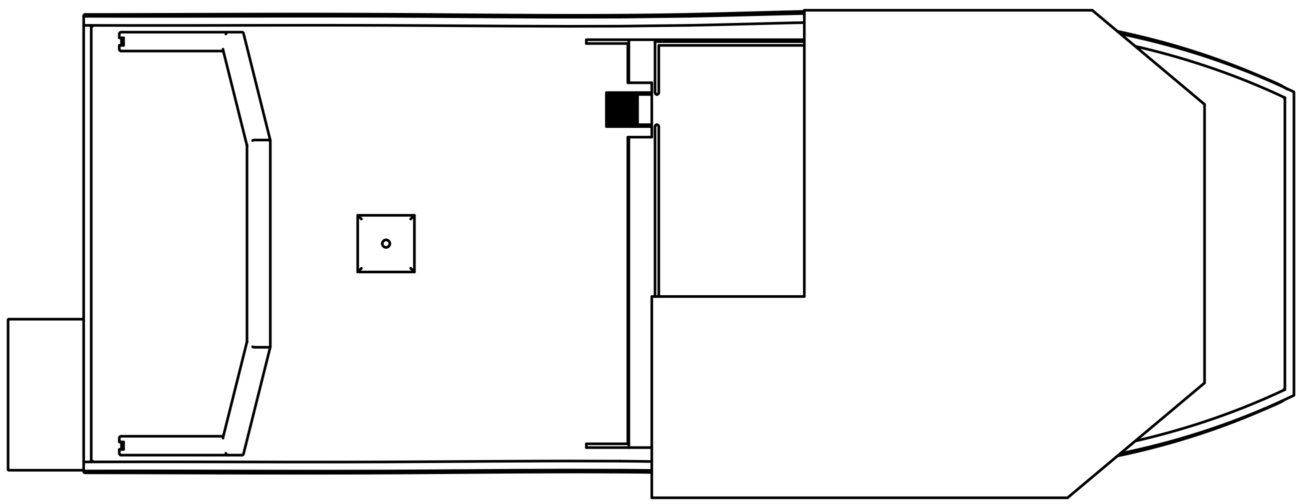
PHONE : +358505686766
EMAIL: alf.norkko@helsinki.fi

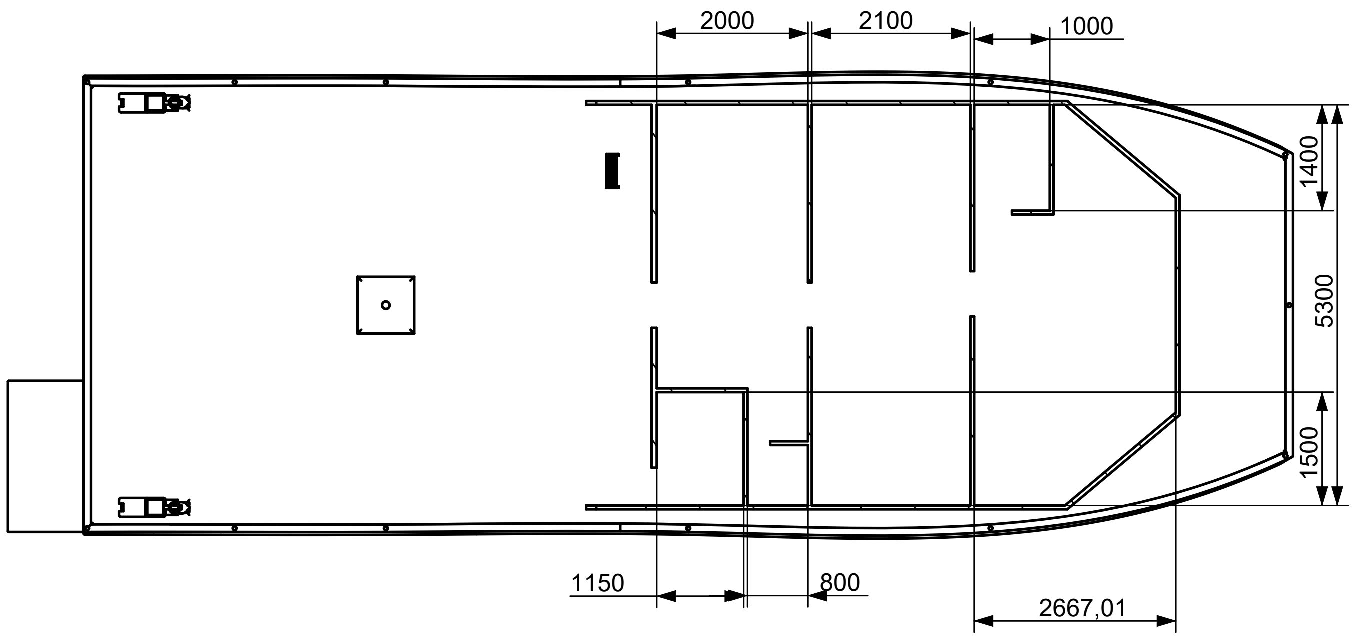
PROJECT COST :

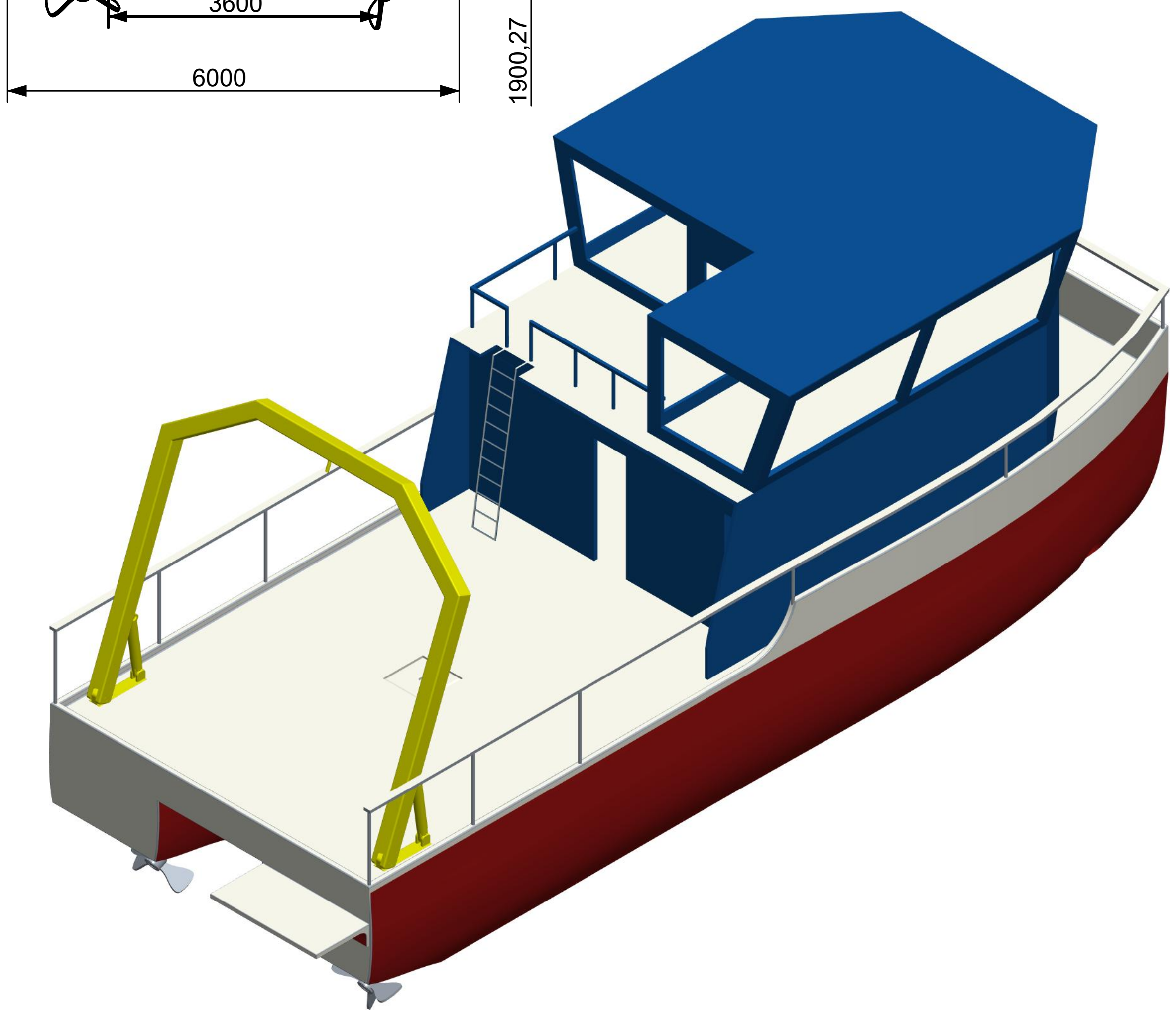
€1,700,000











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Osa Part	Nimike ID-Code	Nimitys Description	Standardi Standard	Kpl Pcs

General to.	Scale 0,010	Product	Customer	
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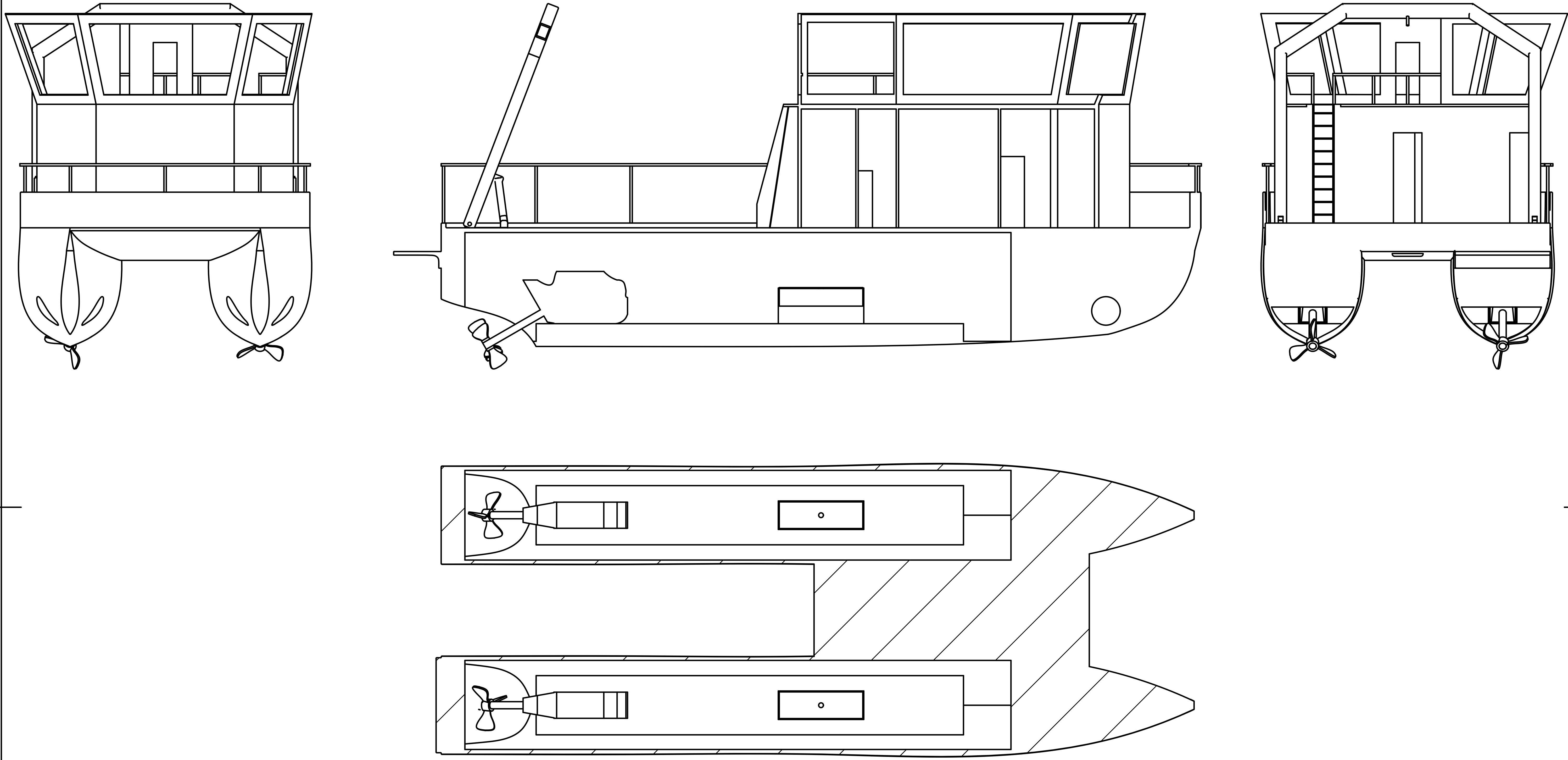
	Design	Date		TVESSEL
Mass	Check.	Date		
kg	Appr.	Date		

Rev.	Change	Date	Changed	Appr.



1				3
Osa Part	Nimike ID-Code	Nimitys Description	Standardi Standard	Kpl Pcs

General to.	Scale 0,012	Product	Customer	

	Rev.		Model name	TVESSEL
	Design	Date	PLAN2	
Mass kg	Check.	Date		
	Appr.	Date		

Rev.	Change	Date	Changed	Appr.

TZS (Proposed) RESEARCH VESSEL

Technical Specification

Length Overall:	16.0m
Beam:	6.0m
Draught:	1.0m
Max Speed:	18kn
Cruising Speed:	14-16kn

Deck

Stern A-Frame with Pullmaster Winch (with remote control) – 2.5 tonne, 4.2m max height, 150m cable (3 tonne)

Side davit – 100kg

Knuckle boom crane – 1.13 tonne @3.5m, 780kg @ 5.3m

Engine room hatches and Moonpool

Aluminium hand rails for both main and raised decks

Diving facilities – kit bench

Self-bailing aluminium deck

Walk-Around Cabin (with Raised Bridge House & Boat Deck)

External Stairs from the work deck to the bridge deck

Main Cabin (Dry Lab)

Interior stairs from dry lab to Raised deck (bridge)

Gear/safety equipment locker

4 person settee Computer workstation with storage lockers

Main Cabin (Wet Lab)

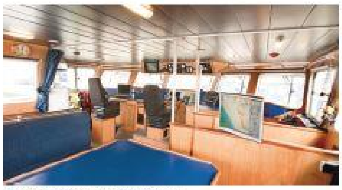
Fresh water sink (drains to sewage tank)

Sea water flush sink (drains directly overboard)

Counter top workstation

Marine Built-in cold room

Appendix B: R/V Callista Technical data



Interior view of R.V. Callista bridge

Interior views of: Wet lab above, and Dry lab left

View of aft working deck

For further details contact:

Mr Gary Fisher
Deputy Superintendent, Ocean and Earth Science,
National Oceanography Centre Southampton,
University of Southampton Waterfront Campus,
European Way, Southampton. SO14 3ZH, UK

tel: +44 (0) 23 8059 6172
fax: +44 (0) 23 8059 6366
email: callista@southampton.co.uk

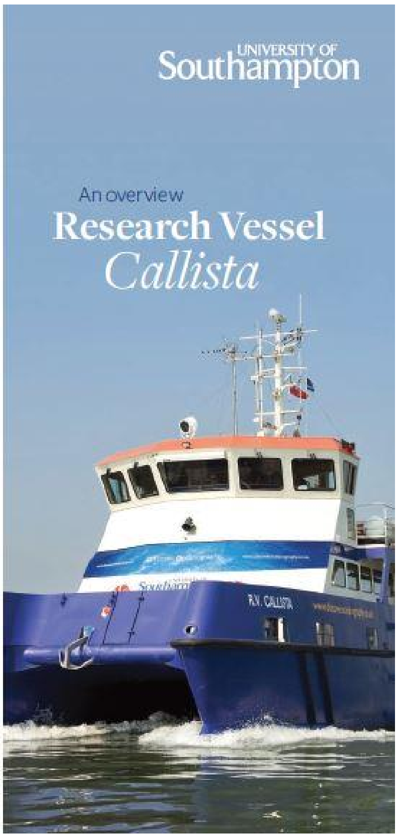
Location

Please see the following website for directions to the NOCS.
http://www.noc.ac.uk/about-noc/find-us

Booking Information

Callista is available for commercial hire, for both inshore and seagoing activities, inclusive of highly skilled crew/technicians.

Examples of organisations that have worked with us recently include:
BAE, for testing the hydrodynamics of their Talisman AUV during development
CEFAS, for deployment and recovery of wave rider buoys
MESL, for grab sampling, ADCP surveys and seabed trawling
OSIL, for equipment testing and customer/staff demonstrations



R.V. Callista

The University of Southampton's RV *Callista* is a 19.75m catamaran, purpose built for teaching and research with a large rear deck and A-frame for equipment deployment.

The vessel offers a unique capability for operations along the south coast for teaching and research as well as a platform for marine enterprise and industry. She is also used in the Discover Oceanography programme which offers the opportunity to experience a hands-on introduction to marine science for groups of all ages.

R.V. Callista is manned by a fully qualified crew of three/four and is designed specifically to undertake a variety of work including:

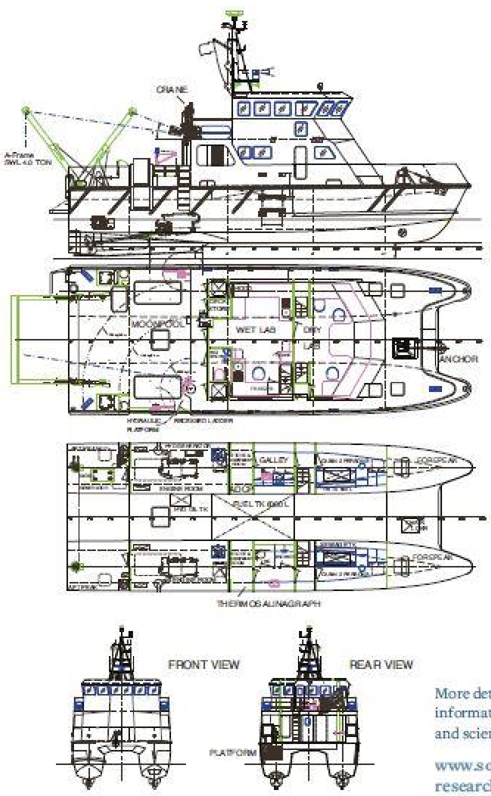
- Deployment of scientific equipment
- Collection of biological, chemical and sediment samples
- Surveying
- Diving operations
- Geophysics
- Educational visits by external groups including schools, colleges, universities and others.

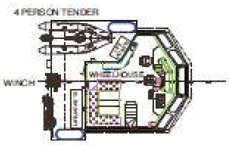
Callista is available for hire, subject to availability.

Callista meaning "most beautiful" is named after a shellfish that is represented both in the Eocene fossils of the Hampshire Basin and in its modern bays and estuaries.

R.V. Callista arriving at the National Oceanography Centre, Southampton.

General Arrangement of
R.V. Callista
(courtesy of UKI WORKBOAT LTD)





Vessel Specifications

Length overall:	19.75m
Beam:	7.40m
Freeboard:	1.70m
Draught:	1.80m
Max Speed:	14kts
Cruising Speed:	10-12kts
Range:	400nm
Accommodation:	4 berths

Certification
UK Class IV Passenger Vessel - max 36 passengers
Workboat category 2, 60mls from a safe haven - max 12 passengers

Deck
Hydraulic Platform Stbd side
Knuckle Boom Crane
3 Phase and Hydraulics available on working deck
Stern 'A' frame & winch
4.5m RIB with outboard motor

More detailed technical specifications and information regarding *Callista's* onboard fitted and scientific equipment can be found at:

www.soton.ac.uk/soes/research/stash/research_vessels.page

Appendix C: R/V Gulf Surveyor Technical data

Boat Specifications

Dimensions:	48' (length) x 17'-7" (beam) x 5'6" (draft)
Air Draft:	23'-9"
Flag:	U.S.
Home Port:	New Castle, New Hampshire
Registry:	Lakes, Bays, and Sounds plus Limited Coastwise
Official Number:	1266419
Lightship Displacement:	17.29 Long Tons
Lab Space:	~12.5' x 9.5'
Top Speed:	18 knots
Propulsion:	2 x Cummins QSB6.7 diesel, 250 mhp @ 2600 RPM, fixed 5-blade propellers
Shipboard Power:	21.5 KW Cummins Onan, 120/240 V AC
Fuel Capacity:	300 Gallons
Potable water:	50 U.S. gallons
Navigation GPS:	Simrad GS25
Navigation Transducer	Garmin GT-41
Fluxgate compass:	Simrad RC42 Rate Compass
Radars:	Simrad DX64s Radar, Simrad Broadband 4G Radar
Autopilot:	Simrad AP70
VHF Radio:	2x iCOM IC-M4240
AIS:	Si-Tex Metadata Class B
Speed/Wind Sensor	Airmar 200WX
Navigation Software:	Rose Point, Coastal Explorer
Acoustic Doppler Current Profiler (ADCP)	RD Instruments WH Mariner 600 kHz Coastal Vessel Mounted DR
Single Beam Transducer:	Odom THP 200/24-4/20
RTK GPS Receiver:	Trimble Trimark 3
Survey GPS Antennas:	2 x Trimble Zephyr Antennas
Positioning and Attitude Sensor:	Applanix PosMV V5 with IMU Type 65
Data Acquisition Software:	Hypack, QINSy

Appendix D: R/V Coastal Carolina Technical data

Dr. Paul Gayes
Coastal Carolina University
Center for Marine and Wetland Studies
1270 Atlantic Avenue
Conway, SC 29526
Tel: 843.349.4015
ptgayes@coastal.edu

8/19/2012

ARMSTRONG DISPLACEMENT CATAMARAN HULL

Length 54', Beam 18'
5086 alloy aluminum .250 bottom plate
5086 alloy aluminum .250 side plates & tunnel
Longitudinal channels welded to bottom plate
Longitudinal hull stiffeners
Self bailing aluminum decks
Aluminum hand rails for main & raised decks
Port & stbd swim platforms c/w ladders to main deck

Deck Accessories

Roof top access ladder
Radar/antenna mast
Port & stbd boarding doors
(2) Engine room hatches c/w gas assist springs
(6) Freeman lift-out hatches
AMI fabricated Tie down sockets in deck fore & aft
Stainless Steel tie-down rings

Assorted Zincs for Corossion Prevention

- Divers Dream Zinc(s)
- Mini Divers Dream
- Bolt on Hull Anode-Zinc
- Shaft Zinc
- Electro Guard Rudder Zincs 5"

(6) Welded aluminum tie up cleats

Anchoring & Moorage
66 lb Claw Anchor
Kinematics 16 x 18 anchor winch c/w 250' 5/8" Sampson rode & 30' 5/16" anchor chain
Recessed bow roller
(6) 3/4" three strand nylon mooring lines 30' each
(6) Black fenders (6" x 25") c/w 10' line
Hydraulic
A-frame c/w Pullmaster PL2 winch (remote controls at aft steering console)
Bow mount sonar apparatus for sonar deployment
H-8 Tulsa 8000# winch

FWD LEAING WALK AROUND CABIN C/W RAISED PILOT HOUSE & BOAT DECK
6'4" headroom for cabin & pilot house
Insulated & paneled c/w FRB & wood trim
Grey Zolatone interior paint
Interior overhead grab rail
Walk-around Pilot House
Bently "Yachtsman" pilot chair for helm station
(2) Survey work stations c/w Tempress chairs
Bench seat c/w storage
Main Cabin
Interior stairs from main cabin to pilot house
Wet gear locker on port side
(4) Survey work stations c/w Tempress chairs
4 person settee c/w storage
Lab Area
Fresh water sink c/w hot and cold mixing faucet (will drain to grey water tank)
Salt water sink w/ faucet and overboard drain (will drain directly overboard)
Counter top working area
Norcold: Marine Built-in Refrigerator
Counter top microwave
Delta DC axial Fan for Computer Rack Closet
Head
Sink c/w mixing faucet
Jabsco ITT Electric Marine Toilet 12V c/w Macerator Pump
Shower c/w adjustable rail for shower head
12 VDC exhaust fan (hard wired)

WATER SYSTEM

100 gallon fresh water tank c/w gauge & redundant sending units
Par Max 7 High Capacity, 12V DC Fresh Water Pump, 7gpm, Even Flow
20 gallon 120 volt hot water tank
100 gallon grey water tank c/w overboard dishcharge valve & macerator pump
55 gallon black water tank c/w overboard discharge, check valve, & macerator pump
Wema Muti Tank Level Indicator for Fuel, Water, Grey Water and Black Water

WINDOWS & DOORS

Pilot House

(3) Fixed winshields c/w pantographic windshield wipers
(2) Triangle windows fwd of helm (port & stbd)
(2) Fixed side windows
(1) Fixed window in aft bulkhead
(1) Sliding side window
(3) Sliding doors c/w windows, solar shades, SS lock set

Main Cabin

(2) Sliding side windows (galley & settee) c/w solar shades
(2) Fixed side windows c/w solar shades
(5) Fixed fwd windows
(1) Fixed window in aft cabin bulkhead
(2) Exterior sliding doors c/w windows & SS locksets
(1) Interior Door for Computer Room

Head

Exterior aluminum swinging door c/w SS lockset
(1) Opaque opening window for head compartment

HVAC SYSTEM

(2) 18,000 BTU Dometic AC units with Heating Core for Main Cabin
(1) 27,000 BTU Dometic AC units with Heating Core for Wheelhouse
Outlets & ducting as required
Wallas 22Dt Diesel Heaters for Wheelhouse

LIGHTING

Hella NaviLED navigation lights including R.A.M.
Golight-Stryker Searchlight-Chrome, 500,000 Candela
(6) 6" LED floodlights (port, stbd, fore, & 2 aft)
(14) Red/white LED dome lights
(8) LED courtesy deck lights
(4) AC powered 24" red/white fluorescent lights
Aqua Signal LED Engine Room Light, 16" x 4.5" x 1", high/low LED's

<u>ELECTRICAL</u>
(2) 8D starting batteries for Cummins engines
(1) 8D house battery (needs to be deep cycle)
(1) Group 31 Battery for Northern Lights generator
Battery Distribution
Blue Sea Custom 360 DC Panels:
Blue Sea 2 x 1 DC Panel
Blue Sea 3 x 4 DC Panel
Blue Sea 2 x 1 DC Bilge Panel
(5) 12v Power Point
(4) Rule 3700gph bilge pumps each hull void with Lighted Switch at Dash
High water alarm system
Twin electric horn

<u>SHORE POWER SYSTEM</u>
<u>Paneltronics Custom AC Panels:</u>
AC Shore & Generator Mains w/ Volt & Amp Meters, 5304 Premier Analog, Paneltronics
AC 24 Position Breaker Panel, 5302 Premier, Paneltronics
AC 6 Position DP Breaker Panel (240VAC), 5303 Premier, Paneltronics
Paneltronics Panel- 200A F Frame Circuit Breaker, 206-529
Paneltronics Panel- Blank Panel, 2001
50 Amp Double Pole Circuit Breaker
50 Amp, 50ft Shore Power Cord-50FT, 3 wire, 125V
50Amp, 125V Inlet, 3 wire, 125V
50Amp Boat Side to 30Amp Shore Power Pigtail Adapter, 125V
(8) GFI Outlets, 2 in Main Cabin, 1 in Pilot House, 1 in Engine Room
(1) Newmar: Phase Three™ “Smart” Battery Chargers
Pro Mariner Pro Safe Deluxe Galvanic Isolator, 60amp
Blue Sea 80A AC C-Series Triple Pole Circuit Breaker

GENERATOR
Northen Lights 20kW Diesel Generator with Start/Stop Remote Panel
2" exhaust system c/w waterlock muffler
1" water system c/w raw water strainer
Blue Sea Battery Switch On/Off

ELECTRONICS PACKAGE

GPS MAP, 6212, 12" Mult Function Display
Garmin High Sensitivity GPS Receiver with Integrated Antenna
Garmin GSD 22 dual frequency network sounder
GMR 18 HD Marine Radar, 18" Radome--24 mile Radar (Network Device)
(2) 504 Icom VHF radios + LOUD Speaker
Stainless Steel Transducer 1kw 50/200 khz-Gemeco-600W-for Garmin Electronics
ICOM HM162 Command Mic III, Black
Command Mic II Extension Cable
Deck/binnacle mount 4.5" magnetic compass

CAMERA SYSTEM

SplashCam Reverse Camera 20/20 VZ with 100' cord

POWER & PROPULSION

Engines

Twin Cummins QSB6.7 - 380HP
(2) Raw water cooling systems c/w sea strainers & ball valves
Exhaust system to suit c/w risers & mufflers
Exhaust bellows, clamps, & fireproof exhaust tubing

Gears

ZF 280 transmissions 2.00:1 ratio
ZF Trol Valves for ZF 280-1A Gears, twin Engine, 12vdc
Live SAE B pad PTO on only one ZF 280-1A

Shafts & Propellers

(2) SS propeller shafts (diameter 2.25")
2 Propellers, 25x23 ZF 4 Blade L & R

Steering & Controls

Cummins Twin Engine Analogue Style Guage Package on J1938
Glenndinning Controls for Twin Engine Twin Station with Troll
Hydraulic steering system c/w (2) cylinders, liquid tie bar, & power assist pump

Rudders

(2) 2" rudder shafts c/w rudder port bearing, upper bearing, & collar
Rudder indicator 2" round
2lb Spray Insulation to Shape

FUEL SYSTEM

(2) 250 gallon aluminum fuel tanks c/w gauges & redundant sending units
(2) Racor dual manifold diesel fuel filters c/w replacement elements
Racor 120 series diesel fuel filter c/w replacement element for Northern Lights generator

ENGINE ROOM & FIRE SUPPRESSION SYSTEM

Fabricated Air Intakes with Air Traps
Engine room insulated c/w 2" & 1-1/2" fiberglass sheeting
Fire Protection for the Wires & Cables
Fireboy fire suppression system c/w (2) 750 cu. Ft. manual/auto extinguishers
Fireboy 5 circuit engine shutdown system
Delta T Axial Fan - 11"
Morse cables & control heads for manual discharge

SAFETY PACKAGE

USCG certified first aid kit
Alcohol Screening Kit, DOT approved for Oral Saliva Testing (3 swabs)
Pelican iM2200 Storm Case, Waterproof for Flares, 16" x 10.5" x 6"
(2) Type B-1, USCG Aproved Kidde Premium Metal Valve Refillable- 5 lb w/bracket in Pilot House
(2) Type B-2, Fire Extinguisher Dry Chemical ABC 10lb, Both Placed Outside Engine Room
(3) CO2 detectors c/w automatic shut down
(2) Smoke detectors
(3) 2.5 Gallon Fire Buckets with Lanyards

Floatation & Lighting

(1) 25 person viking life rafts c/w containers & hydrostatic release for Offshore (greater than 50nm from shore)
(24) USCG Type 1 adult life preservers USCG, UL Approved Type 1 Adult PFD
(3) USCG Type 1 child life preservers USCG, UL Approved Type 1 Child PFD
Category 1 406 EPIRB
(2) 30" life ring c/w reflective tape & mounting bracket
100' Rescue Mate throw rope
USCG approved overboard strobe light c/w 6V battery
Hand held safety horn c/w 9V battery
(2) Hand held LED lights

Placards

Oil Discharge Plaque
Drug Warning Plaque
General Alarm Plaque
Injury Report Plaque
Carbon Monoxide Warning Plaque
Pollution Prevention Plaque

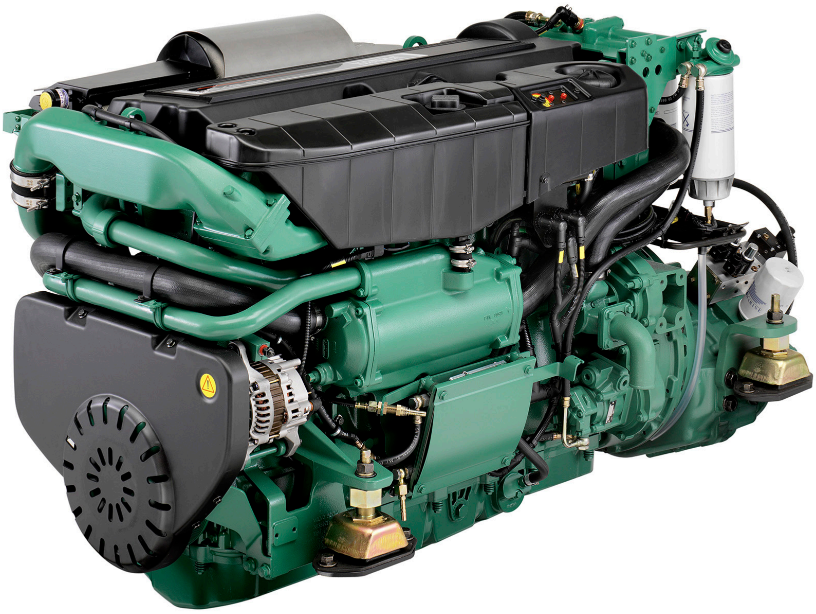
PAINTS & FINISHES

Clear coat for hull topsides
Anti Fouling Black E Paint for Hull below water line
Durable non-skid for deck
Striping & decals as specified
Interior GreyStone Zolatone Paint
White Buskote on Rooftop Exterior

Appendix E: Volvo Penta D9-500 Technical Data

VOLVO PENTA **INBOARD DIESEL**

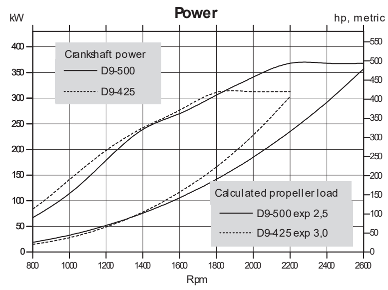
D9-425/500

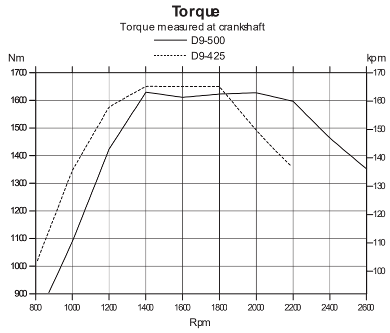


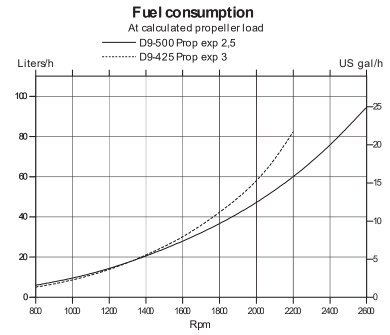
Technical Data

Engine designation	D9-425 (R3)	D9-500 (R4)
No. of cylinders and configuration	in-line 6	in-line 6
Method of operation	4-stroke, direct-injected, turbocharged diesel engine with aftercooler	
Bore/stroke, mm (in.)	120/138 (4.72/5.43)	120/138 (4.72/5.43)
Displacement, l (in^3)	9.4 (571)	9.4 (571)
Compression ratio	20.2:1	17.4:1
Dry weight bobtail, kg (lb)	1075 (2370)	1075 (2370)
Dry weight with reverse gear ZF305A-EB, kg (lb)		1205 (2657)
Crankshaft power, kW (hp) @ 2200 rpm	313 (425)	
Crankshaft power, kW (hp) @ 2600 rpm		368 (500)
Max. torque, Nm (lbf.ft) @ 1400 rpm	1651 (1217)	1630 (1202)
Emission compliance	IMO NOx, EU IWW, US EPA Tier 2	
Recommended fuel to conform to	ASTM-D975 1-D & 2-D, EN 590 or JIS KK 2204	
Specific fuel consumption,		
g/kWh (lb/hph) @ 2200 rpm	222 (0.36)	
g/kWh (lb/hph) @ 2600 rpm		217 (0.352)
Flywheel housing/SAE size	11,5"/SAE2	

Technical data according to ISO 3046 Fuel Stop Power and ISO 8665. With fuel having an LHV of 42700 kJ/kg and density of 840 g/liter at 15 °C (60 °F).
Merchant fuel may differ from this specification which will influence engine power output and fuel consumption. Ratings R3 & R4, see explanation in Volvo Penta's Sales Guide.







VOLVO PENTA

D9-425/500

Technical description:

Engine and block
- Cylinder block and cylinder head made of cast-iron
- One-piece cast-iron cylinder head
- Ladder frame fitted to engine block
- Replaceable wet cylinder liners and valve seats/guides
- Drop forged crankshaft with induction hardened bearing surfaces and fillets with seven main bearings
- Four valve per cylinder layout with overhead camshaft
- Each cylinder features cross-flow inlet and exhaust ducts
- Gallery oil-cooled cast aluminum alloy pistons with three piston rings
- Rear-end transmission

Engine mounting
- Flexible engine mounting (option)

Lubrication system
- Integrated oil cooler in cylinder block
- Symmetrically positioned twin full flow oil filter of spin-on type and by-pass filter

Fuel system
- Electronic Unit Injectors, one per cylinder, vertically positioned at the center in between the four valves
- High pressure injector nozzles
- Gear-driven fuel pump, driven by timing gear
- Electronically controlled central processing system (EMS – Engine Management System)
- Electronically controlled injection timing
- Single fine fuel filter of spin-on type, with water separator and water alarm

Air inlet and exhaust system
- Air filter with replaceable inserts
- Mid-positioned twin entry turbocharger with aftercooler
- Wet exhaust elbow (option)

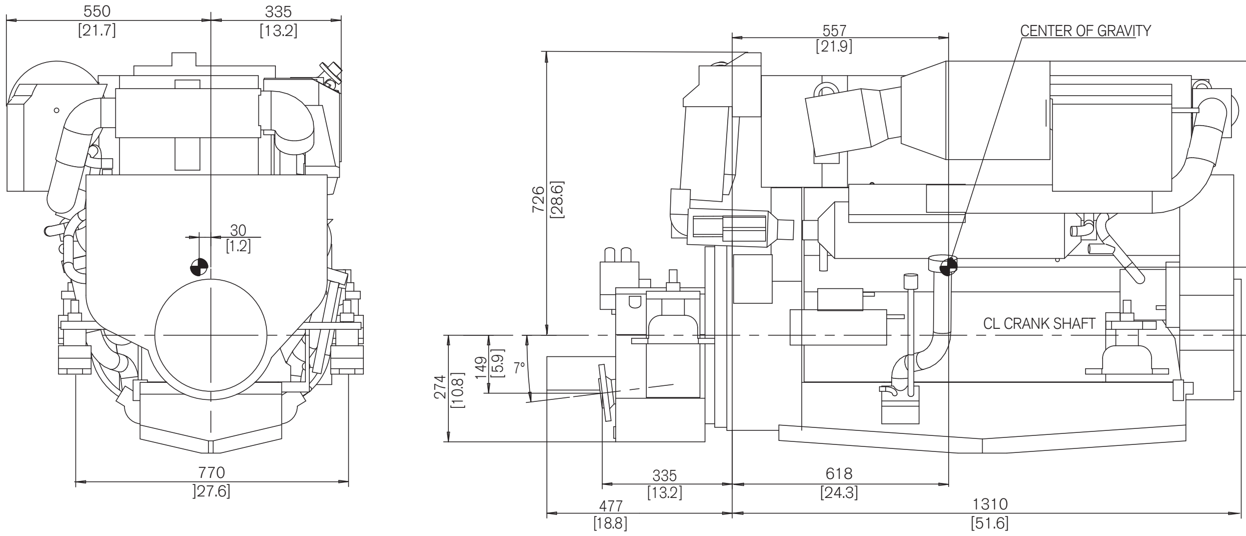
Cooling system
- Seawater-cooled tubular heat exchanger
- Coolant system prepared for hot water outlet
- Easily accessible seawater impeller pump in rear end

Electrical system
- 24V/80A alternator

Instruments/controls (option)
- Complete instrumentation including key switch and interlocked alarm
- EVC monitoring panels for single or twin installations
- Electronic shift and throttle
- Plug-in connectors

Reverse gear
- MG5075AE/IVE (R4), MG5065AE (R4), and ZF286AE/IVE, electronically shifted. Low Speed/Trolling as option for ZF286.

Dimensions D9-425/500 with ZF286AE
Not for installation



More information

Contact your local Volvo Penta dealer for more information regarding Volvo Penta engines and optional equipment/accessories or visit www.volvopenta.com

IOS

Android

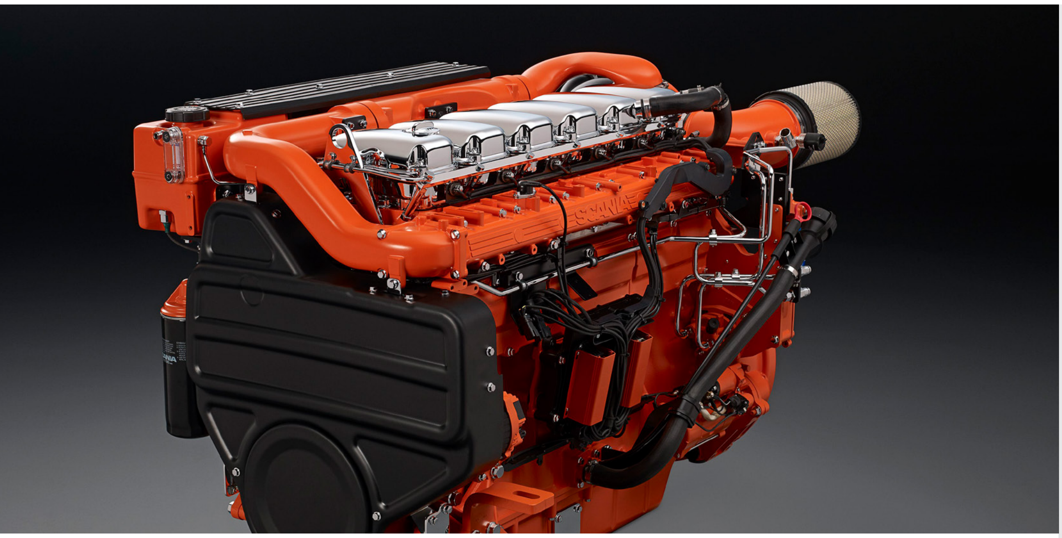
Download the Volvo Penta dealer locator App for your IPhone or Android

AB Volvo Penta
SE-405 08 Göteborg, Sweden
www.volvopenta.com

Appendix F: Scania Marine Engine DI13 092M Technical Data

DI13 092M. 368 kW (500 hp)

IMO Tier III, IMO Tier II, EU Stage IIIA



The marine engines from Scania are based on a robust design with a strength optimised cylinder block containing wet cylinder liners that can easily be exchanged. Individual cylinder heads with 4 valves per cylinder promotes repairability and fuel economy.

The engine is equipped with a Scania developed Engine Management System, EMS, in order to ensure the control of all aspects related to engine performance. The injection system is based on electronically controlled unit injectors that in combination with SCR (Selective Catalytic Reduction) gives low exhaust emissions with good fuel economy and a high torque already at low revs.
The engine can be fitted with many accessories such as air cleaners, PTOs, transmissions, cast iron flywheel housing with dual positions for starter and type approved instrumentation in order to suit a variety of installations.

		Engine speed (rpm)		
	Rating	1200	1500	1800
Gross power, full load (kW)	ICFN	292	350	368
Gross power, full load (hp, metric)	ICFN	396	476	500
Gross power, propeller curve (kW)	ICFN	134	233	368
Gross power, propeller curve (hp, metric)	ICFN	182	317	500
Gross torque (Nm)	ICFN	2320	2227	1952
Spec fuel consumption. Full load (g/kWh)		193	190	196
Spec fuel consumption. 3/4 load (g/kWh)		193	190	195
Spec fuel consumption. 1/2 load (g/kWh)		194	195	203
Spec fuel consumption. Propeller curve (l/h)		31	53	86
Optimum fuel consumption (g/kWh)		191		
Reductant consumption. Full load (g/kWh)		19	19	19
Reductant consumption. Propeller curve (l/h)		2.0	4.0	5.2
Heat rejection to coolant (kW)		198	223	246

ICFN – Continuous service: Rated power available 1 h/1 h.
Unlimited h/year service time at a load factor of 100%

Standard equipment
- Scania Engine Management System, EMS
- Unit injectors, PDE
- Turbocharger
- Fuel pre-filter with water separator
- Fuel filter
- Oil filter, full flow
- Centrifugal oil cleaner
- Oil cooler, integrated in block
- Oil filler, in engine block
- Oil dipstick, in block
- Starter, 2-pole 7.0 kW
- Alternator, 2-pole 100A
- Flywheel SAE 14
- Silumin flywheel housing, SAE 1 flange
- Front-mounted engine brackets
- SCR-system
- Protection covers
- Closed crankcase ventilation
- Operator's manual

Engines with heat exchanger:
- Impeller sea water pump
- Heat exchanger with expansion tank

Optional equipment
- Hydraulic pump
- Side-mounted PTO
- Front-mounted PTO
- Exhaust connections
- Scania instrumentation 2.0
- Type approved instrumentation
- Engine heater
- Engine bracket with different heights
- Stiff rubber suspension
- Air cleaner
- Cast iron flywheel housing, SAE 1 flange
- Reversible fuel filter
- Low coolant level sensor
- Low and extra low oil sump
- Reversible oil filters
- Long oil dipstick
- Oil level sensor
- Reductant feed pump
- Bilge pump

Engines with heat exchanger:
- Self priming sea water pump

This specification may be revised without notice.

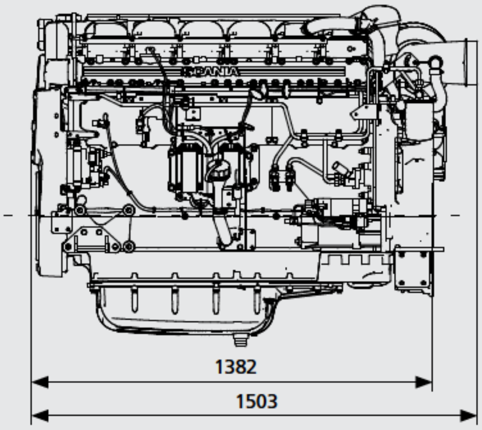
SCANIA MARINE ENGINES

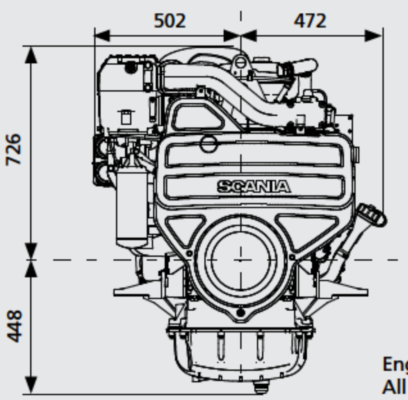
DI13 092M. 368 kW (500 hp)

IMO Tier III, IMO Tier II, EU Stage IIIA

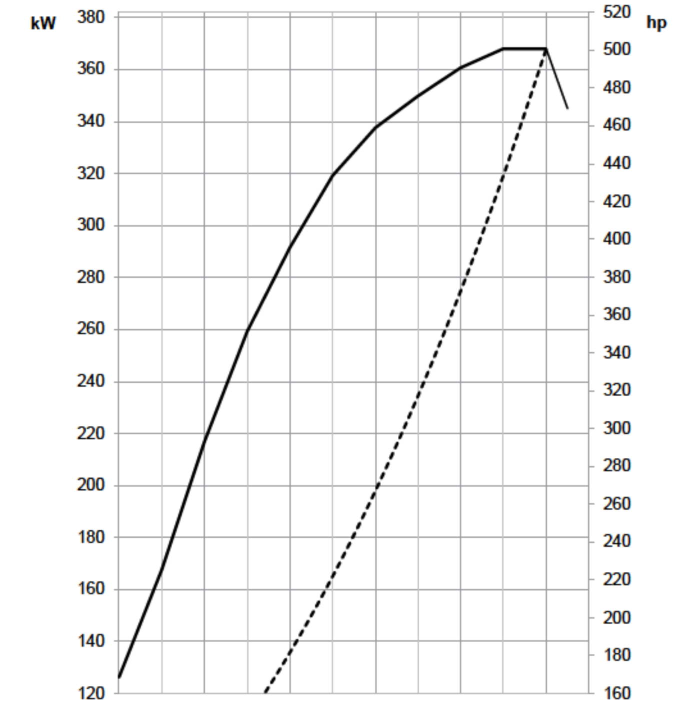
Engine description

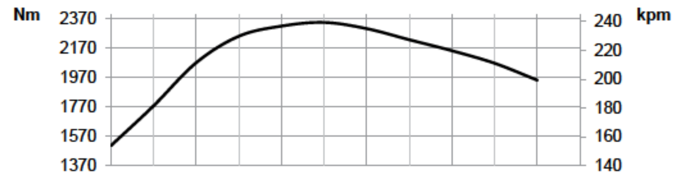
No of cylinders	6 in-line
Working principle	4-stroke
Firing order	1 - 5 - 3 - 6 - 2 - 4
Displacement	12.7 litres
Bore x stroke	130 x 160 mm
Compression ratio	17.3:1
Weight (excl oil and coolant)	1285 kg (Engine with heat exchanger) 1180 kg (Engine with keel cooling)
Piston speed at 1500 rpm	8.0 m/s
Piston speed at 1800 rpm	9.6 m/s
Camshaft	High position alloy steel
Pistons	Steel pistons
Connection rods	I-section press forgings of alloy steel
Crankshaft	Alloy steel with hardened and polished bearing surfaces
Oil capacity	28-34 dm³ (standard oil sump)
Electrical system	2-pole 24V

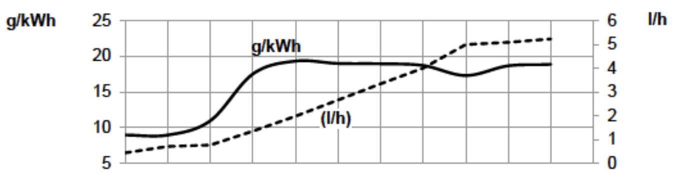


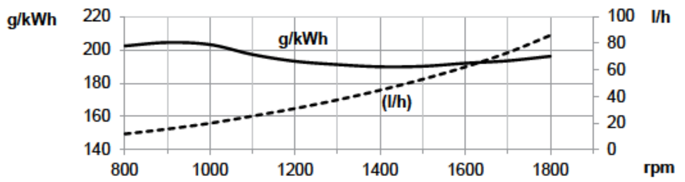


Engine with heat exchanger
All dimensions in mm









Propeller curve, assumed exponent 2.5
Full load curve

SCANIA
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Telephone +46 8 553 810 00
Telefax +46 8 553 829 93
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engines@scania.com

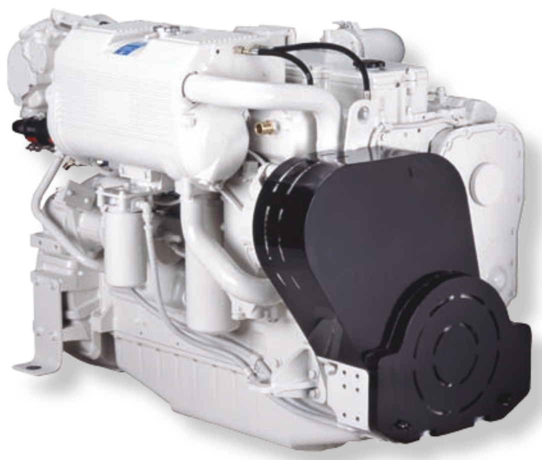
Test conditions Air temperature +25°C. Barometric pressure 100 kPa (750 mmHg). Humidity 30%. Diesel fuel acc. to ECE R 24 Annex 6. Density of fuel 0.840 kg/dm³. Viscosity of fuel 3.0 cSt at 40°C. Energy value 42700 kJ/kg.
Power test code ISO 3046. Power and fuel values +/-3%.

QSC8.3

Marine Propulsion Engines for Recreational Applications

General Specifications

Configuration	In-line, 6-cylinder, 4-stroke diesel
Aspiration	Turbocharged / Aftercooled
Displacement	8.3 L (505 in³)
Bore & Stroke	114 X 135 mm (4.49 X 5.31 in)
Rotation	Counterclockwise facing flywheel
Fuel System	High Pressure Common Rail



Product Dimensions and Weight

Overall Length	mm (in)	1422.0	(55.99)
Length of Block	mm (in)	856.0	(33.70)
Overall Width	mm (in)	977.5	(38.48)
Overall Height	mm (in)	981.6	(38.65)
Weight	kg (lb)	896	(1975)

Dimensions and weight may vary based on selected engine configuration.

Power Ratings

Engine Model	Output Power kW	Output Power MHP	Output Power BHP	Engine Speed RPM	Rating Definition	Fuel Consumption Rated Speed L/hr (gal/hr)	Fuel Consumption ISO* L/hr (gal/hr)	Emissions IMO	Emissions EPA	Emissions EU	Emissions RCD
Variable Speed											
QSC8.3	368	500	493	2600	High Output	96.0 (25.4)	66.0 (17.4)	2	3	—	1
QSC8.3	404	550	543	3000	High Output	113.0 (29.9)	76.0 (20.1)	2	3	—	1
QSC8.3	441	600	592	3000	High Output	122.7 (32.4)	80.9 (21.4)	2	3	—	1

* Average fuel consumption based on ISO 8178 E3 Standard Test Cycle (variable speed models) and ISO 8178 D2 Standard Test Cycle (fixed speed models)

QSC8.3

Marine Propulsion Engines for Recreational Applications

Features and Benefits

Engine Design – Unmatched performance from industry-leading power density on this four-valve-per-cylinder engine. Maximize vessel performance and access comprehensive vessel diagnostic information via SmartCraft® electronics. Peace of mind delivered by the Cummins Captain's Briefing and global service network

Fuel System – Improved fuel economy and sociability from Cummins high pressure common rail fuel system; handed spin-on engine mounted fuel filter

Lubrication System – Handed spin-on engine mounted lube filter, cast aluminum oil pan

Cooling System – Sea water heat exchanger cooling system

Air Intake System – New Walker air filter significantly reduces noise

Exhaust System – Cast water cooled exhaust manifold for lower surface temperatures, safety and improved performance

Electronics — 12v and 24v Quantum System electronics feature a proven ECM to monitor operating parameters such as fuel consumption, duty cycle, engine load and speed, while providing diagnostics, prognostics and complete engine protection. Simplified electrical customer interface box for all vessel connections to reduce installation complexity

Certifications – Complies with U.S. EPA Tier 3 emissions regulations without the use of aftertreatment. Designed to meet the International Association of Classification Societies (IACS) and SOLAS requirements. Consult your local Cummins professional for a complete listing of available class approvals.

Optional Equipment

- Engine Controls: Digital Throttle and Shift; Electronic Throttle and Shift (ETS) and optional potentiometer for mechanical controls
- Instrumentation: SmartCraft® digital displays and/or analog gauges provide data on engine speed, oil pressure, engine load and more
- Vessel System Integration: SmartCraft® monitors fluid level, vessel range, depth, vessel speed, rudder position, temperatures and more

Cummins is a pioneer in product improvement. Thus specifications may change without notice. Illustrations may include optional equipment.

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Bulletin 4087253 Rev. 10/15